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TEXT-BOOK

OF

MILITARY ENGINEERING,

FOR THE USE OF THE

CADETS OF THE UNITED STATES MILITARY ACADEMY.

PART I.

PERMANENT FORTIFICATIONS.

BY

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BREVET-COLONEL, U. S. ARMY.

UNIVERSITY

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PREFACE.

THIS Text-book is prepared specially for the use of the cadets in studying the course of Fortification at the United States Military Academy.

The object of the book is to give a clear statement of the general principles and rules observed by engineers in the construction of modern fortifications.

The student after having mastered these principles can prosecute intelligently his future studies relating to the development of the art of fortification, and the history of the various systems employed in the past.

A due regard for the limited time allowed to the cadet for instruction in this course of study has made it necessary to avoid, as far as possible, all details not absolutely necessary for a thorough understanding of the subject. Many details in the way of explanation and illustration are left to be supplied by the instructor in the class room.

J. B. W.

WEST POINT, N. Y.,
January, 1884.

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INTRODUCTION.

FORTIFICATIONS are coeval with man, and are recognized by the great masters of "the art of war" as important adjuncts of all military operations. Their object has not changed with time. It is to strengthen a position that has been selected for defence, so that a body of troops posted in the position, can fight advantageously an enemy that could not be repulsed successfully by this same body in the open field.

A position is strengthened for this purpose, at the present time, by arranging it so that its defenders are sheltered from an enemy's fire, and are able to retard, if not entirely stop, an enemy's approach to it.

The shelters from the fire and the obstacles obstructing the approach of an enemy are combined so as to destroy, or, at least, weaken the effect of the enemy's weapons, at the same time allowing a strong offensive action upon the part of the defenders.

The first object sought for in a fortification is the repulse of an enemy's attack. It follows, therefore, that fortifications are essentially defensive in their character.

Fortifications are indispensable auxiliaries of an army obliged to act defensively.

There are two general cases where an army is forced to act defensively. The one case is that of an army in the immediate presence of an enemy superior to it; this superiority being due to greater numbers, to the better

quality of the weapons, to the kind of troops, to recent successes, or to other causes. The other case is that of an army charged with the duty of defending a large area of country from invasion.

In the first case, the army acknowledging the superiority of the enemy in its front, feels it necessary to occupy a position and wait for the enemy to attack. With this object in view, the army takes a position such that there shall be obstacles in its front to obstruct the enemy's approach, and such that its flanks cannot be easily turned. If obstructions do not exist naturally, they are supplied by fortifications that are constructed in the emergency, or may have been prepared in anticipation of their need. If the position be not too extended, the army waits for the attack, and feels sanguine of being able to resist it successfully.

In the other case, the army defending a large area of country is obliged to scatter its forces and to occupy points guarding the approaches to the objective of the enemy. These points are not in close defensive relations with each other, and are necessarily occupied by numbers less than those that an enemy can concentrate against any one of them. Important as fortifications were to an army of the first case, they became doubly so to an army of the second case, since any one of these points is liable at any time to be attacked by an enemy superior in numbers. The success of the enemy in attacking one of these points might lead to his breaking through the general line of defence, and seizing the communications of the defensive army with its base.

Fortifications are not only useful to defensive armies, but they are also useful to armies acting offensively.

However superior an army acting offensively may be, there are times that it must be content to act upon the defensive. Prudence and good judgment also demand that its lines of communications and its flanks should be made safe, which is

done by posting troops in strongly intrenched positions on the flanks and in its rear. The stronger and the more durable the fortification, the less will be the number required to hold it, and the greater will be the numbers allowed to act with the main body of the army in its forward movements.

It has been said by a high military authority that a defensive war cannot be systematically and successfully waged in a country not provided with fortifications planned and distributed according to strategical requirements.

As to the value of fortifications during a war, Napoleon said, "If fortified places can neither secure a victory, nor stop the progress of a victorious enemy, they can, at least, retard his progress and give more time for the defence to act."

MILITARY ENGINEERING.

PART I.

PERMANENT FORTIFICATIONS.

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CHAPTER I.

ART OF FORTIFICATION.

1. Art of Fortification. — The means employed to strengthen positions selected for defence, are called **fortifications.** The planning, laying out, and constructing of fortifications belong to a branch of Military Engineering termed the "art of fortification."

The **art of fortification** may be defined to be "that branch of Military Engineering which has for its object **the strengthening of positions selected for defence.**"

2. Temporary and Permanent Fortifications.—It is usual to divide fortifications into two principal classes, viz.: **temporary** and **permanent.**

In time of war, many places acquire a special military value, which makes it important that they should not fall into the hands of the enemy. The value thus acquired may be only temporary, or it may be permanent.

Places oftentimes acquire this special value from being near an enemy, and lose it again when the enemy changes his position, or when some change has been made in military operations. Positions of this kind are usually strengthened

by fortifications hurriedly constructed from such materials as may be obtained in the vicinity, and are usually occupied only for a limited period. The fortifications thus constructed belong to the **temporary** class, and are those which are described in treatises on "field fortifications."

In every country, points are to be found which, in case of war, are certain to become of great military importance, and the defence of which will be essential, either as a matter of safety to the country, or as an element necessary for the success of the military operations of its armies.

Most countries make it a duty to strengthen such points, before the necessity arises for their use. The fortifications built for this purpose are carefully planned and well constructed. They are made strong and durable, and are furnished with the means of making an obstinate resistance, when well manned. Fortifications of this kind belong to the **permanent** class.

Although more time and greater care are necessary in the construction of permanent fortifications than in the construction of temporary ones, the general principles of the art of fortification are equally applicable to both classes.

3. General Value of Permanent Fortifications.—Permanent fortifications possess a value in addition to the simple one of strengthening positions selected for defence. With permanent fortifications well planned and properly built, the positions which they strengthen can be safely held by a much smaller number of troops than would otherwise be necessary to defend them. This additional value gives the power to the government of increasing the size of its armies in active service, without endangering too much the safety of the important positions which are to be held.

Positions thus strengthened can be safely held by troops inferior in numbers or in kind, who would not, without the protection of the fortifications, be able to resist successfully

the attacks of an enemy. Positions defended by permanent works also form rallying points for troops falling back before an enemy's advance, or for troops retreating after a defeat.

4. Modern Fortification.—Permanent fortifications have been more or less used by man from the earliest periods of history to the present time. They are divided frequently into classes corresponding to the divisions employed in history, viz.: **ancient, mediæval,** and **modern** fortifications.

Modern fortification, the subject of this treatise, owes its origin to the changes produced in the art of war by the introduction of gunpowder as an element of warfare.

The fortifications of the mediæval period consisted of walls of masonry, which entirely surrounded the place to be defended. The walls were ordinarily from six to twelve feet thick, and even more than this in many cases; and were high enough to make escalade difficult or impossible. The walls were flanked by towers placed along the faces of the walls, from forty to fifty yards apart. These flanking towers were either circular or rectangular in plan, and were sometimes made a part of the wall, and sometimes were detached from it. When detached, communication from them to the top of the wall was had by means of temporary bridges. The walled cities and feudal castles of the middle ages are types of the fortifications in use when gunpowder was first employed in military operations.

The success which followed the use of gunpowder in breaching the walls and in blowing open the gates of the fortifications of the period, caused modifications and changes to be made in existing works, and in the plans of new fortifications, for the purpose of having these works offer a greater resistance to the attacks of this new agent. Out of these modifications and changes, modern fortification, as an art, had its beginning.

5. Siege Artillery.—The modifications in fortifications

resulting from the use of gunpowder can be better understood when the methods of using it, at the time of its introduction, to make breaches in walls, are known. Siege equipments and battering machines are as old as permanent fortifications themselves, and their use in sieges dates from the earliest periods of history. The equipments and battering machines of the ancient Greeks and Romans were very complete, and were effectively employed in many noted sieges. The employment of gunpowder modified and effected changes in the siege equipments and machines in use at the time, as well as in the fortifications of that date. Battering rams, catapults, and machines of similar character soon disappeared, and were replaced by new machines and improved methods, in which gunpowder was used.

The earliest use of gunpowder in siege operations is ascribed to the Genoese, who employed it in the year 1319. The contrivance or piece in which it was used was first known as a **vase**, from its general form; but this name was soon changed to **bombard**, by which it is better known. The bombard was a hollow conical frustum, made of bars of wood or iron, put together like the staves of a barrel, and firmly bound around by bands of iron.

Some of these bombards were very large. Froissart mentions one that was used at the siege of Oudenarde, in 1382, which, he says, was fifty feet long. He probably means that the bombard and its carriage, both together, were of that length.

The method of constructing the bombard by binding bars of iron together was soon abandoned, and the method of casting the piece of bronze was adopted.

The bombard is the forerunner of the heavy siege gun now in use. Simultaneous with the development of the bombard, lighter pieces in which gunpowder was used were devised. These lighter pieces have their representatives at the present time in the field artillery.

Leaden balls were fired from the light pieces, and balls of stone from the bombards. Cast-iron shot were first made in 1471. It was not a long time after their introduction before they were used instead of those of lead or stone. The use of cast-iron shot had the effect to decrease the size of the bombards, and to increase the calibres of the light pieces.

The method of attacking a fortified place, in the time of bombards, was to first employ the light pieces to drive the defenders from the loop-holes, and then to bring forward the bombards close to the walls. The fire of the bombards was then directed upon the part of the wall to be breached or upon the gate to be knocked open, and continued until a breach was made or the gate battered in. As soon as an opening was effected, an attempt was made to take the place by an assault through the breach.

The frequent success of these artillery attacks was the primary cause which led to the modifications of the then existing fortifications, and to the changes in the systems used.

6. Modifications of Fortifications.—The masonry walls which formed the fortifications of this period were not backed by earth, nor, as a rule, were they surrounded by ditches. There was, therefore, no obstacle to an assault, after a breach in the walls had been made. And, as a breach was quickly made by the bombards after they were in position, there was not time to construct a new wall within the old one, as had been done frequently in ancient sieges, when battering rams and similar machines were used to breach the walls.

The success of Charles VIII. of France in taking many of the towns in Italy in the latter part of the 15th century, by simple artillery attack, proved conclusively to engineers of the period that the fortifications then existing could not resist successfully the attack of siege artillery then in use, and that to resist successfully, the fortifications must be strengthened.

The best method of resistance being to strike back with blows as heavy, or heavier than those received, it became evident that artillery should be used in the defence of fortifications. But the masonry walls of that date were not suitable for the use of artillery. It became necessary, therefore, to make arrangements so that cannon could be mounted and used against the besiegers.

If strong enough, and not too high, the old walls were left standing and earthen ramparts made back of them, upon which cannon could be mounted. The flanking towers were cut down to the same level as the top of the walls, and were filled solidly with earth. Thus modified and armed with cannon, the strength of the fortifications was greatly increased.

In the construction of new fortifications, care was taken to make the walls strong enough to support the rampart. The proper height of wall to prevent escalade was obtained by sinking a ditch below the surface of the ground, and by building up the wall from the bottom of the ditch to the proper height. By this method, the top of the wall was brought nearer to the surface of the ground, at the same time preserving the proper height deemed necessary to make it secure from escalade, and screening a great portion of the masonry from the besiegers' guns.

The towers were gradually replaced by projections from the wall, pentagonal shape in plan, which allowed a fire along the face of the wall, and a cross fire on the ground in front of it. These projections were called **bastions**, and were first used in Italy, where the necessity of modifying the fortifications had been first most keenly felt.

The resulting modifications of the mediæval fortifications were in course of time systematized, and the resulting system became known to engineers as the **Italian system**, or **bastion system** of fortification.

The principal objects sought to be attained by this system may be stated to be as follows:

1. To make arrangements by means of which artillery could be employed in the defence;

2. To improve the flank defences;

3. To give better protection to the entrances of fortifications, and secure them from being carried by assault;

4. To increase the thickness of the masonry walls of the fortifications and shelter them from the direct fire of an enemy.

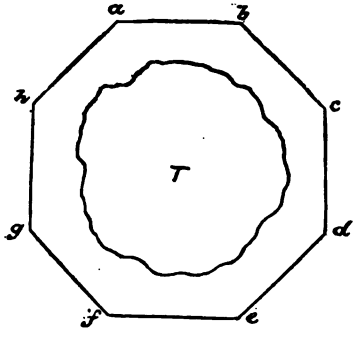
Great improvements have been made in the methods devised for obtaining these objects since the era of modern fortification begun. Further improvement in the methods is still sought for by engineers of the present day, and many plans have been devised by them having these objects in view. These plans are described in histories of permanent fortification, in which the details are to be found.

CHAPTER II.

THE RAMPART AND PARAPET.

7. Front of a Fortification.—When a given place, as a town, T (Fig. 1), for instance, is to be fortified, the place is supposed to be entirely surrounded by a broken line, *a*, *b*, *c*, etc., forming a polygon, the lengths of the sides, *a b*, *b c*, etc., being dependent, in modern fortification, upon the system of fortification to be used.

Fig. 1.



Previous to the era of modern fortification, walls of masonry would have been built, the faces of which would have coincided with the sides, *a b*, *b c*, etc., of the polygon. At the salients, *a*, *b*, *c*, etc., and at other intermediate points, where necessary, flanking towers would have been built. These walls and towers would have formed the fortifications of the place.

At the present time, each of the sides of the polygon would be defended by works constructed according to the rules of the system, or the method of fortification, to be used to fortify the place. If the sides and angles of the enclosing polygon are all equal, the polygon is a regular one, and the forti-

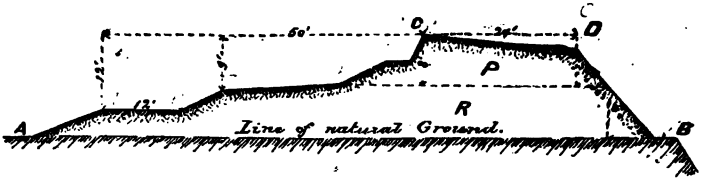
fications constructed are called **regular.** When the polygon is an irregular one, the fortifications are said to be **irregular.**

The works constructed to defend any one of the sides, as *a b*, of the enclosing polygon form what is called a **front**, and the line *a b* is called the **exterior side** of the front.

Instead of the high masonry wall of the mediæval period, an earthen rampart, surmounted by a parapet, is employed to enclose the place.

8. Rampart.—The rampart, **R** (Fig. 2), is a bank of earth which supports a parapet, **P**, so arranged as to allow those using it as a shelter to sweep the ground in front of it with their fire.

Fig. 2.



It is seen that the rampart adds to the height which an enemy has to surmount in making an assault; it hides the enclosed space surrounded by it from the view of an enemy; and it gives to the men defending the place a commanding position from which they can fire upon the ground exterior to the fortification.

The upper surface of the rampart in rear of the parapet is called the **terre-plein.** It should be at least eight feet below the upper line of the parapet, so as to screen those standing upon it from the enemy's view.

The terre-plein must be wide enough to allow room for the guns which are to be used in defending the work, and also for a roadway in rear of the guns. A distance of from forty to fifty feet will be required for these purposes. In the older works, the roadway was taken at the same level as the plat-

forms of the guns; but now it is considered advisable to have the roadway placed at a lower level, not less than twelve feet below the upper line of the parapet. This is necessary to shelter those using the roadway from projectiles with a descending trajectory which just graze the parapet. The slope of the rampart connecting the upper surface with the natural ground in rear, has the inclination of the natural slope of the earth forming the rampart, or something less. For convenience, the natural slope is assumed to be $\frac{1}{1}$, and is so taken in the figure. In practice, the slope is sometimes made $\frac{2}{3}$, and sometimes $\frac{1}{2}$. Where it is important to have as large a space enclosed as possible, the **rampart slope** is replaced by a retaining wall. The interior space is called the **parade**, and this retaining wall is known as a **parade-wall.**

The upper surface of the rampart is made with a gentle inclination to the rear, to allow the rain water which falls upon it to flow off.

Communication between the parade and terre-plein is by means of **ramps** and **stairs.** Ramps are inclined roads connecting two surfaces at different levels, their width and slope depending upon the uses to be made of them. The sides of the ramps are connected with the parade by slopes of earth, or by retaining walls, as in the case of the rampart.

9. Parapet.—The parapet of a permanent fortification does not differ in principle from that employed in field works.

The upper line, **C** (Fig. 2), of the parapet is termed the **interior crest**, and is at least *eight* feet above the terre-plein in rear of it.

The inclination of the upper surface, or **superior slope**, of the parapet is such as to allow the ground, exterior to the fortification and near to the work, to be swept by the fire over the interior crest. An inclination of $\frac{1}{6}$ is given to the superior slope in Figure 2. This is the greatest that should be used, and a less inclination is to be preferred when practicable.

The exterior surface of the parapet which connects the superior slope with the upper surface of the rampart is called the **exterior slope** of the parapet. It has the same inclination as the natural slope of the earth used for the parapet, or something less. A small step, or terrace of earth, is placed on the inner side of the parapet, with its upper surface four feet and six inches below the interior crest, for the purpose of allowing men to stand upon it and fire over the parapet.

The upper surface of this terrace is called the **banquette tread,** and is made five feet wide. When the work is ready for defence, the banquette tread is connected with the interior crest by a revetted slope of earth, called the **interior slope,** or by a wall termed a **breast-height** wall.

When a temporary revetment is employed, the interior slope is made with an inclination of $\frac{3}{1}$.

When a breast-height wall is used, the wall is made vertical, or with a slight batter, and rises to within eighteen inches of the interior crest. The portion of the parapet above the top of the wall is left at the natural slope of the earth, or is revetted with sods.

It is usual in permanent fortifications to leave the interior slope at the same inclination as the natural slope of the earth, giving it the proper inclination and revetting it only when occasion requires it to be made ready for use. When this is the case, a width of three feet of the banquette tread will be covered by the base of the interior slope, and but two feet will remain uncovered.

The banquette tread is connected with the terre-plein by steps, or by a slope of earth termed the **banquette slope.** The inclination of the banquette slope is usually made $\frac{1}{2}$.

The intersections of the surfaces of a parapet are given particular names to distinguish them from each other. Where the intersection makes a salient angle with the plane of site, the line is called a **crest;** if it is a re-entering angle, it is

termed a **foot.** The intersection of the interior and superior slopes of a parapet is the line called the **interior crest**; that of the superior and exterior slopes is called the **exterior crest,** etc.; while the intersection of the interior slope with the banquette tread, being re-entrant with respect to the plane of site, is called the **foot of the interior slope,** etc.

A similar rule is applied to the intersections of other surfaces of a fortification, the plane of comparison for determining the kind of angle being taken below the intersections considered.

The **rule** for the thickness of a parapet requires that *the thickness should not be less than one and a half times the penetration of the projectile used against it into the earth of which it is made.*

The thickness depends, therefore, upon the kind of earth used in the construction of the parapet and upon the amount of penetration of the projectiles used against it. Experiments show that a parapet made of sand, exposed to direct fire of siege guns of the present day, should have a thickness, **C D** (Fig. 2), of not less than twenty-four feet. Sand resists the penetration of projectiles better than any other earth used for parapets.

10. Ditch.—The earth for the rampart is obtained from the **ditch,** which should be arranged as an obstacle to an assault. It may be either wet, or dry; the location of the site will generally determine which. If the ditch is a **wet** one, and the water in it is at least **six feet** deep, it will be an obstacle to an assault very difficult to overcome.

If the ditch is a **dry** one, it is usual to arrange it as an obstacle by building walls against its sides; the **height** and **steepness** of the walls forming the obstacle to an assault.

The sides of the ditch are known as the **scarp** and **counterscarp,** and the walls are distinguished from each other by these names; the wall on the side of the ditch next to the

work being called the **scarp wall,** and the one on the opposite side the **counterscarp wall.**

Wet ditches, when wide and with six feet or more of water in them, are formidable obstacles; but they have the disadvantages of confining the garrison to a passive defence, and of making the site unhealthy, especially when the water is stagnant. Dry ditches, with steep and high scarp and counterscarp walls, are great obstacles to an assault, but are costly to construct. Moreover, while they afford serious obstacles to an assault, these obstacles are more easily overcome in the final stages of a siege than those offered by wet ditches.

11. Scarp and Counterscarp Walls.—To form an obstacle of any value to the defence, a wall should be so high that ladders will have to be used to climb over it. A wall which is twelve feet or more high cannot be climbed without the aid of ladders, or other devices of a similar kind. A wall twenty feet high cannot be safely descended without such means. Scaling ladders usually form a part of the siege equipments of an army, and have been successfully employed on some occasions to climb walls of moderate height.

Scarp walls of the main work are usually made so high that an attempt to escalade them will be an exceedingly difficult operation, and in the presence of a vigorous defence, almost an impossible one. Engineers consider a height of thirty feet to be the least which the main scarp wall should have. Walls to form obstacles to an assault should therefore be at least **twelve feet** high, as this will compel the assailants *to use ladders* to overcome them; to form obstacles to escalade, they should be not less than **thirty feet** high.

Masonry walls, if exposed to direct fire, cannot withstand successfully the projectiles of modern siege artillery. Where they would be exposed to such fire, the masonry must in some way be protected. This is usually done by screening the walls from the enemy's view, and by interposing masses

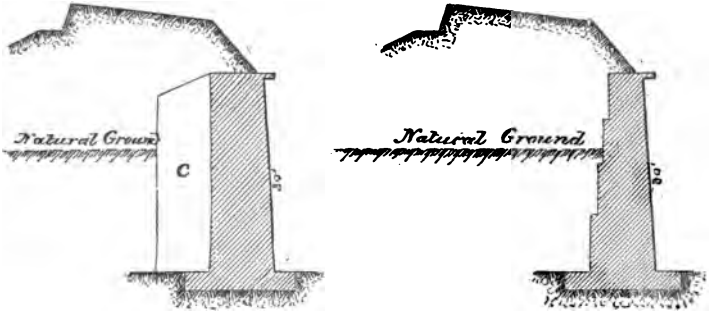
of earth to intercept or to deflect the enemy's projectiles. The use of earthen masses supplemented by the use of iron or steel plates, will be more or less used in future constructions.

Care is taken to build the walls so as to add as much as possible to the difficulties of breaching them, and so as to limit the breach to those portions of the walls actually destroyed by the projectiles.

There are three kinds of scarp walls, viz.: the **ordinary retaining** wall; the retaining wall with **relieving arches**; and the wall wholly, or partly, **detached** from the scarp.

The ordinary retaining wall (Fig. 3) is the kind most gen-

Fig. 3.



erally found in the older fortifications. It may be built with the back vertical, or with a batter, or with the back broken into offsets.

A scarp wall of this class is usually built with counterforts (C) placed from fifteen to eighteen feet apart, and either rectangular or trapezoidal in plan.

The trapezoid is the more common form, and its dimensions are determined by certain rules laid down by engineers. The following is a rule that has been recommended:

Representing the height of the scarp wall by h; the length of the side joining the back of the wall is made equal to $\frac{1}{5}h$;

the length of the opposite side is made $\frac{2}{15}h$; and the depth, or length of the counterfort, is $\frac{1}{4}h$.

The thickness of a scarp wall is determined by the rules laid down for retaining walls. A scarp wall made with a mean thickness equal to one-third of its height will, in general, possess sufficient stability for a retaining wall.

Counterforts are considered a great addition to the scarp walls, since they retain the earth, after the wall has been breached, at a slope too steep to be used by an assaulting column. Further work must therefore be done, after the breach has been made, to render it a practicable one.

By springing arches from one counterfort to the next, the thickness of the scarp wall may be diminished with safety, since these arches will support a part of the pressure of the earth which otherwise would have to be supported by the wall. A breach in the wall would not then bring down the parapet, as it would still be held up by the arches. Scarp

Fig. 4.

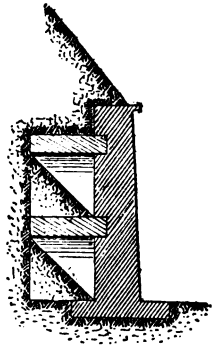
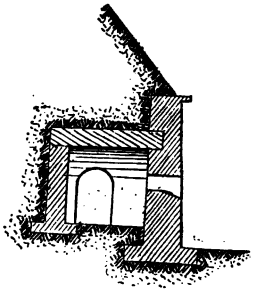


Fig. 5.



walls of this kind are examples of retaining walls with relieving arches.

The arches may be in one or more tiers (Fig. 4), their number depending upon the height of the scarp wall. The upper surface of the top row of arches should not be less than

three feet below the top of the scarp wall, so as to allow for sufficient earth over the arches to make them bomb-proof.

For a span of twelve feet, a thickness of eighteen inches and a rise of three feet may be used for the arch. If the arches are intended only to support the earth, the latter is allowed to rest upon the backs of the arches, taking its natural slope (Fig. 4). If the arches are to be utilized as galleries, bomb-proofs, etc., the earth is excluded from the backs by building a wall along the back of the counterforts (Fig. 5). This wall may be straight or curved in plan, depending upon the amount of thrust the wall may have to sustain. A curved wall is considered the better one to be used when the thrust is great.

Arched passage-ways through the counterforts afford communication between the different rooms.

Detached scarp walls (Fig. 6) are built simply to be obstacles. A wall of this kind is usually built in the bottom of

Fig. 6.

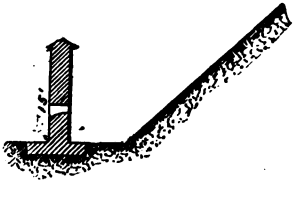
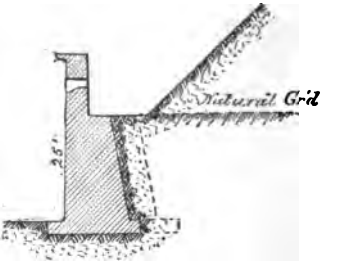


Fig. 7.



the ditch at a short distance from the foot of the scarp, so as to leave sufficient room for a roadway between the back of the wall and the scarp, and carried up to the proper height.

Partly detached scarp walls (Fig. 7) are built as retaining walls for a part, and as simple walls for the rest of their height. The example shown in Figure 7 is a retaining wall from the bottom of the ditch to the level of the natural ground, and a simple wall for the rest of its height.

Partly detached walls are sometimes called **semi-detached** walls.

Scarp walls of the third class are usually loop-holed. When exposed to enfilade fire, the walls are frequently provided with arched recesses to shelter the men using the loop-holes.

A roadway is made in rear of a partly detached wall to afford communication along the wall. A roadway of this kind is called a **chemin-de-ronde.**

Detached scarp walls cost less for their construction than do the simple retaining walls, and are considered to offer a greater obstacle to an assault, since the attacking party has to descend from them, as well as to climb them. The use of detached walls has the effect of diminishing the interior space of the main work by requiring a greater length of exterior slope. This requirement, where space is of great importance, makes the ordinary revetment wall preferable in some cases.

A counterscarp wall adds to the difficulties of making an assault, and, when sufficiently high, forms an obstacle of considerable importance. The least height of such a wall, to be useful as an obstacle, is **fifteen** feet. Placed as it is upon the side of the ditch next to the enemy, it cannot be breached by his fire, nor can it be overcome until the enemy reaches it.

In some permanent fortifications a counterscarp wall is not used, the counterscarp being left at the natural slope of the earth, or a slope something less. When this is the case, earthen masks are placed in the ditch to protect the masonry of the scarp wall.

In wet ditches, the water is a sufficient obstacle when deep enough. Wet ditches, therefore, are not usually revetted, although in some of the older works masonry is used.

12. Command and Relief.—The height of the interior

crest of a fortification above the plane of site is called the **command** of the work over its site; the height of the interior crest above the bottom of the ditch is called the **relief** of the work.

If a work has its interior crest higher than that of one near it, the former is said **to command** the latter.

When the command of a work is fixed, the height of the rampart is determined; the command and relief being fixed, the depth of the ditch is determined.

13. Ravelin.—The entrances of fortifications consist of openings in the rampart and parapet, or of bomb-proof passage-ways made under the parapets and terre-pleins. The entrances are placed in the parts of a fortification where they will be most secure from capture by assault, and are protected by works placed opposite to them and beyond the ditch.

In the earlier days of modern fortification, the form of work employed to guard and to protect the main entrance was in many cases semicircular. This work was called a **demi-lune.** Later the form was changed to that of the redan, and the work was then generally known as the **ravelin,** though it was often called a demi-lune. The names have now in a great measure become interchangeable, although preference is given to the later name by recent writers.

14. Covered Way.—Beyond the ditch and along its border a roadway is constructed entirely around the main fortification and its ravelins, for the use of the troops forming the garrison. This roadway is screened from the enemy's fire by a parapet, and is called a **covered way.**

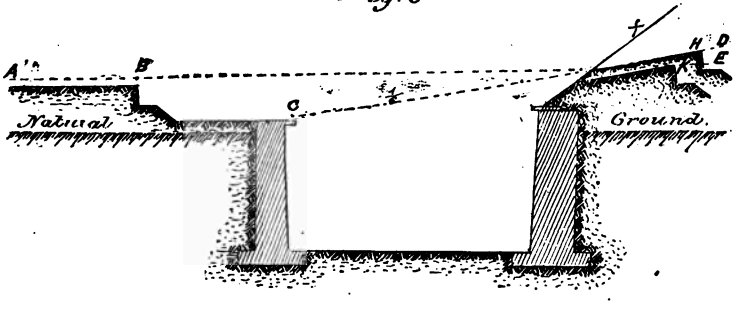
The parapet used to shelter the covered way differs from the ordinary parapet, in having its superior slope prolonged until it intersects the surface of the ground. This upper surface of the parapet is made with quite a gentle slope, and is called a **glacis.** The roadway screened by this parapet may

be upon the surface of the ground, above, or below it. The interior crest of the screening parapet must be high enough above the roadway to shelter the troops when using it. The slope of the glacis, or inclination of the superior slope of the parapet, should be such as to allow its surface to be swept by the fire of the works in rear of it.

Problem.—Supposing the height of the interior crest of the covered way and the slope of the glacis to be fixed, let it be required *to find the limits within which the interior crest of the main work should be found so as to sweep with its fire the glacis in front of it.*

The line of fire of the main work should pass within one foot and a half of the crest of the counterscarp; therefore the superior slope of the parapet when produced should not pass a greater distance than this above the counterscarp. Through **C** (Fig. 8) draw a right line, **C D**, with the slope of $\frac{1}{6}$ (the slope of the parapet), and this will represent the lowest line of fire.

Fig. 8



The fire from the main work should reach the foot of the glacis, and in doing so should pass far enough above the crest of the covered way to make it safe for the troops standing upon its banquette; let four feet be the least distance for this purpose. Through the foot of the glacis and a point, **B**, four feet above the crest of the covered way, draw

the right line **B E**; this will represent the line of fire passing four feet above the crest of the covered way.

It is evident that to fulfil the above conditions, the interior crest of the main work must lie between the lines **B E** and **C D**, and that points like **H** and **K** on these lines indicate the highest and lowest positions the interior crest can have when these conditions are satisfied.

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CHAPTER III.

SYSTEMS OF FORTIFICATION.

15. Trace.—The general outline or configuration in plan of a fortification, either upon the ground or drawn on paper, is termed its **trace.**

The directrix or line used to mark out the trace is called the **magistral**, or "master-line," since all lines of the trace are dependent upon this particular one for their position.

In temporary works, the sub-crest or projection of the interior crest is used as the directrix; in permanent fortifications, the line of intersection of the face of the scarp with the top of the wall when a wall is used, or the line of intersection with the natural surface of the ground when no revetment is used, is the magistral line.

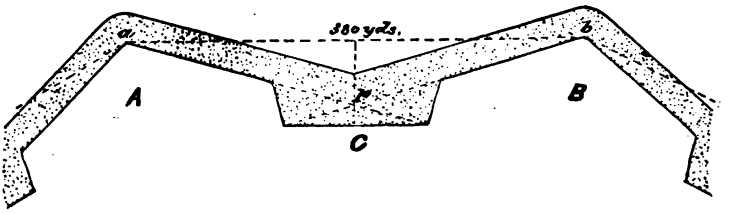
The intersection of the face of a wall with its top is its magistral, the wall being determined in position by this line when the batter and height of wall are given. When the word magistral is alone used, it is understood to apply to the line of intersection of the face of the scarp with its upper surface.

16. Systems of Fortifications.—Many kinds of traces of fortification have been devised by engineers. Many of these traces have had a practical application; many are theoretical, never having been tested by experience.

They may all, however, be classed under four general heads, or **systems,** which are known as the **bastion,** the **polygonal,** the **tenaille,** and the **circular** systems.

17. Bastion System.—The trace of a front planned in accordance with the rules of the bastion system is shown in Figure 9.

Fig. 9.

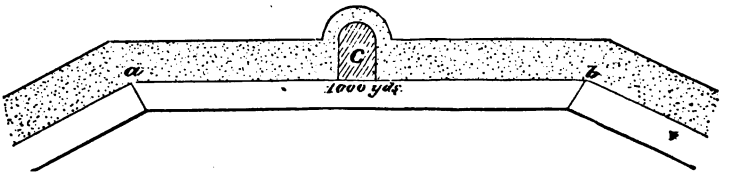


The salients of the bastions, A and B, are placed at the salients, *a* and *b*, of the polygon circumscribing the area to be fortified. The flanks are connected by a straight portion, C, called the curtain, which is made parallel to the exterior side, *a b*. When this curtain is of the proper length, the ditch can be thoroughly swept by the fire of the flanks.

An examination of this trace shows that strong direct and cross fires can be brought upon the ground in front of *a b*; strong flank fires upon the ground in front of the salients at *a* and *b*; and that the ditches can be thoroughly flanked by the fire of the work itself. But that to obtain these advantages the lines of the bastion are more or less exposed to enfilade and reverse fires.

18. Polygonal System.—The trace of a front fortified

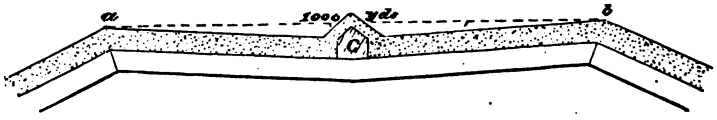
Fig. 10.



according to the rules of the polygonal system is shown in Figure 10, and also in Figure 11.

In the polygonal system, the magistral of the front coincides with the exterior side, *a b*, as in Figure 10; or it may vary slightly from it, as seen in Figure 11.

Fig. 11.

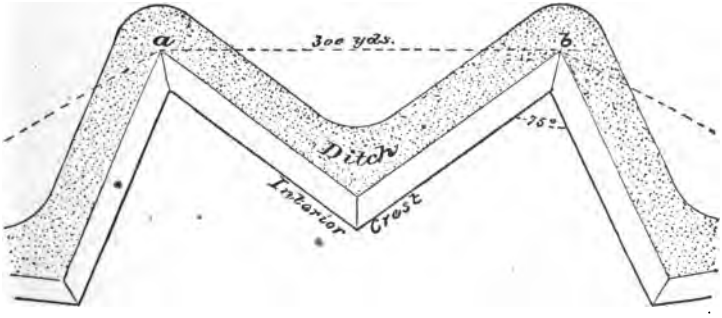


The ditches are flanked by fire from constructions, **C, C,** placed in the ditches called **caponiers.**

The angles of the enclosing polygon at the salients *a*, *b*, etc., are made as obtuse as possible, so as to keep the prolongations of the faces near to the adjacent fronts, and to prevent their being exposed to enfilade.

This trace shows that a strong direct fire can be had upon the ground in front of the work, and that there is less exposure of the faces to enfilade and reverse fire than in the bastion trace. These advantages are obtained, however, at the sacrifice of the cross fire of the main work. This trace does not allow the ditches to be flanked by the fire of the main work as in the bastion trace, but compels the use of constructions exterior to the main work to obtain a flank fire.

Fig. 12



19. Tenaille Trace.—The trace of a front planned by the rules of the tenaille system is shown in Figure 12.

In a trace constructed according to the rules of this system, the re-entering angles are never made less than 90°, nor greater than 120°.

An examination of the tenaille trace shows that a strong cross fire from the work can be brought upon the ground in front of the line *a b*, and a strong flank fire upon the ground in front of the salients *a*, *b*, etc.

It is also seen that the principal lines of the main work are liable to be exposed to enfilading and reverse fires, and that the ditch is only partially flanked by the fire of the main work. These disadvantages are so great, that it is only in special localities that this trace possesses sufficient advantages to make it expedient to use it.

20. Circular System.—When the principal lines of the work are curved lines, the work is said to belong to the **circular** system.

Examples of fortifications belonging to this system are to be found among the older works. The serious disadvantage of not being able to concentrate the fire of a circular front upon a given point, makes it improbable that this system will be employed in the future, excepting in special cases.

21. Characteristic Features.—The characteristic feature of the bastion system is that the salient and re-entrant angles of the trace are not alternate, the re-entering angles being opposite to each other (Fig. 9).

The characteristic feature of the polygonal system is the absence of re-entering angles in the trace (Fig. 10); or, if there be any, that the re-entrants are very shallow (Fig. 12).

The characteristic feature of the tenaille system is that the salient and re-entrant angles of the trace are alternate.

The characteristic feature of the circular system is that the principal lines of the trace are curved.

22. Active and Passive Defence.—If during an attack of a fortification the garrison sally from the main work and

attack the enemy, the defence made is called **active.** If the garrison make no attempt to sally from the work, but confine their resistance to a defence behind the parapets, the defence is then called **passive.** An active defence is to be preferred when the numbers of the garrison justify it.

In the traces of the four systems of fortification as described, no provision is made for an active defence. A garrison defending a work whose trace is like one of those just described, upon emerging from the ditch, would be immediately exposed to an enemy's fire and driven back into the ditches before the necessary formations could be made. Protection must be given to the garrison in making sorties if an active defence is to be made.

This protection is obtained by using other defensive works exterior to the main one. These works are placed in close defensive relations with the main work, and besides facilitating an active defence, tend to prolong the resistance which the garrison offers to capture. Works placed in close defensive relations with the main work are called **outworks.** The ravelin (Art. 13) and the covered way (Art. 14) are examples of outworks.

In many cases, works are placed in advance of the outworks to strengthen the main work. Works of this kind are known either as **advanced works,** or as **detached works,** according to the positions they occupy and the objects to be attained by them.

Descriptions of the works exterior to the main one will be given hereafter.

CHAPTER IV.

THE BASTION SYSTEM.

23. Bastion Trace.—The bastion system of fortification is said by military writers to have been first used in Italy. The exact date of the employment of the bastion in a fortification is not known, although it is known that the bastions of the old fortifications of Verona were built somewhere between 1525 and 1560 A.D.

The bastion trace, when first used, was characterized by small bastions and very long curtains. The great distances of the bastions from each other made it impracticable, with the fire-arms of the period, to cross the fire of the faces upon the ground opposite the middle of the curtains. The object of the faces of a bastion in the early trace was not so much to obtain this fire as to give shelter to the adjacent flanks.

The great importance of this particular cross fire was soon recognized by engineers, and to obtain it engineers placed the bastions nearer to each other; in so doing shortening the length of the curtains. To give a strong fire the faces were lengthened, and in consequence the bastions were increased in size.

The earliest modification of the bastion trace was seen in the enlargement of the bastion and in the shortening of the length of the curtain. Various circumstances, such as peculiarities of site, improvement of fire-arms, etc., produced in time other modifications of the trace, until at length the modern trace was evolved.

The trace taken to illustrate the principles of the bastion system and its methods of construction is the one that, until quite recently, was employed by engineers. Modifications of this trace, both actual and theoretical, have been made and proposed, but whether they are to be accepted, or they and the whole system to be cast aside, form questions now under discussion among engineers.

After the appearance in Italy of the bastion system its principles soon became known throughout Europe. There was scarcely an European power which did not employ Italian engineers, or engineers who had served in Italy, to build new fortifications according to its rules, or to modify existing ones by making them conform to the principles of the bastion system.

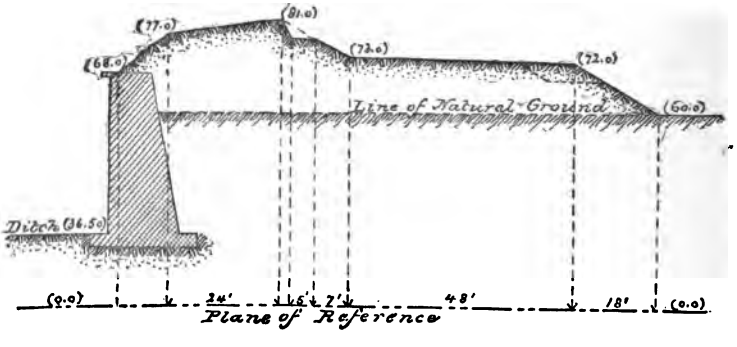
France was among the first to adopt the system and make a comprehensive application of its rules to her fortifications. The great military prestige of France had its influence upon neighboring nations, and her example was followed by them. At the close of the seventeenth century the bastion system was practically the only system in use, and was the type of modern fortification of the period. The French took the lead in modifying the trace as it was received from Italy, and in systematizing the rules to be followed in using it. The changes made by the French, and the universal application of the system to the fortifications of France, so completely identified the system with that country that it practically lost its name of Italian, and became more generally known as French. Hence military writers in speaking, as they do, of the "**Modern French System,**" mean by it to designate the bastion system of fortification.

24. Dependence of Trace on the Relief.—One of the principles of the bastion system is to have the ditches of the main work thoroughly swept by the fire of the work itself (Art. 17). This condition makes the trace dependent upon

the relief, and the converse. It is seen that a longer curtain is necessary if the relief be made greater, and a shorter one if the relief be made less. Assuming a particular relief, the least length of curtain which will allow the ditch in front of the curtain to be swept by the fire of the flank is determined; or, assuming a given length of curtain, the greatest relief of the flank becomes fixed. The height of the interior crest of the work above the bottom of the ditch, or the relief, becomes a factor of the trace in its construction.

25. Profile.—A section made by a plane passed perpen-

Fig. 13.



dicular to the directrix of a work at any point is termed a **profile.** The dimensions of the profiles are not always the same, in consequence of the relief of the work being greater in some parts than in others. In describing the method of constructing the trace, the fortification is supposed to be located upon a level site, and to have dry ditches. The profile taken at the middle point of the curtain of the main work is that one in which the relief is the least.

To make the method determinate, the dimensions of this profile are assumed to be as follows (Fig. 13):

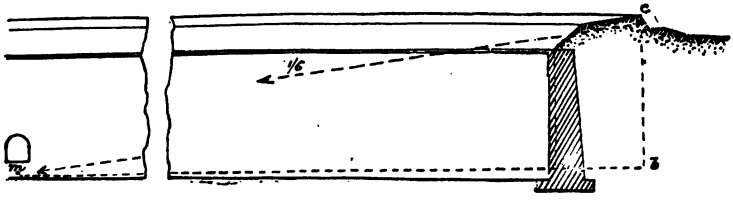
The height of interior crest above plane of sight is 21′.0; above banquette tread, 4′.5; above crest of rampart slope,

9′.0; and above bottom of main ditch, 44′.5. The thickness of parapet, 24′.0, and of terre-plein, 48′.0. The inclination of the superior slope is $\frac{1}{6}$; of exterior slope, $\frac{1}{1}$; of interior slope, $\frac{3}{1}$; of banquette slope, $\frac{1}{2}$; of rampart slope, $\frac{2}{3}$. Width of banquette tread, 5′.0; width of berme, 1′.5. The walls have a batter of $\frac{24}{1}$.

These dimensions are taken within the limits given in Chapter II., and for the purpose of making the constructions definite.

26. Length of Curtain.—The ditch of the curtain is swept by the fire of the adjacent flanks. This can be effectively done when the fire of each flank reaches the bottom of the ditch at or near the middle of the curtain. The fire used is an embrasure one, the sole of the embrasure having the same inclination as that of the superior slope of the parapet.

Fig. 14.



The line of fire of the embrasure is assumed to be **three** feet below the interior crest. Its greatest depression in the case of an open embrasure will be at a slope of $\frac{1}{6}$, or the same as the inclination of the sole of the embrasure. A line drawn with an inclination of $\frac{1}{6}$ through a point three feet below the interior crest, will therefore fix the limit below which the bottom of the ditch cannot be reached by the fire of the embrasure.

Pass a vertical plane through the foot of the curtain, intersecting the flanks. Let *c* (Fig. 14) be the interior crest, and *m* a point eighteen inches above the bottom of the ditch at

the middle of the curtain. At a distance of three feet below c and parallel to the superior slope draw a straight line. This line should pass through or below m, if the ditch is to be swept by a fire of the flanks.

To find the least length of curtain which will admit this condition, assume the dimensions given in Figure 13 for the profile at the middle of the curtain. The interior crest c is above m a distance of forty-three feet. The line $m\,b$ is therefore 240 feet long. The length of the magistral of the curtain for this distance will be represented by $m\,a$, and equal to 240 feet less the distance $a\,b$.

The distance $a\,b$ is composed of the thickness of the parapet, 24 feet; the base of the exterior slope, 9 feet; and the width of the berme, or distance from the foot of the exterior slope to the magistral, taken to be 1.5 feet. Adding these together gives $a\,b = 24' + 9' + 1'.5 = 34.'5$. Subtracting this from 240 feet gives $m\,a$ equal to 205 feet, or $410' = 136.6$ yards for the least length of magistral of curtain for the assumed relief of $44'.5$. A less distance than this will cause the line of fire to pass above m, and leave a portion of the bottom of the ditch which will not be reached by the fire of the embrasure.

The distance 136.6 yards, is therefore the *least* length of magistral of curtain which will allow, with the assumed profile, the main ditch to be thoroughly flanked by embrasure fire of the main work.

The greatest length of curtain depends upon other circumstances. Besides sweeping the ditch of the curtain, the entire ditch of the front should be swept by the fire of the flanks. Hence, the curtain should not be too long, or it might interfere with this purpose. It is also a condition that the faces shall cross their fire upon the ground in front of the curtain. If the curtain is too long, this condition may not be satisfied.

The effective range of the arm used to flank the ditches,

the skill necessary to use the weapons, and the limits of distinct vision of the soldier, are elements which affect the consideration of greatest length. Besides these, there are other elements due to site and other circumstances, which must be fully considered when the question of greatest length is to be decided.

To make the construction a definite one, in the trace to be described the curtain is taken to be 136.6 yards long.

27. Length of a Flank.—The object of a flank, to sweep the ditch, requires that the flank should be at least long enough to be armed with two pieces of artillery. Its greatest length need not exceed that which will give room enough for as many guns to be mounted on the flank as there may be guns mounted by an enemy upon the opposite glacis to counterbatter it.

The length of the flank, in a given trace, will vary with its position with respect to the curtain and face. To sweep the curtain ditch effectively, the flank should be perpendicular to the magistral of the curtain; to do the same for the face, the flank should be perpendicular to the magistral of the face. A compromise between these two is made by giving the flank a position such that it will make *an angle of about* 100° *with the curtain.* With the length of curtain just assumed, this will make the flank about *fifty* yards long.

28. Direction and Length of Face.—Unless there are peculiar circumstances which require a deviation from the rule, the magistral of the face lies upon the line joining the salient of the circumscribing polygon and the intersection of the magistrals of the flank and curtain. The intersection of the flank with the face fixes the length of the face.

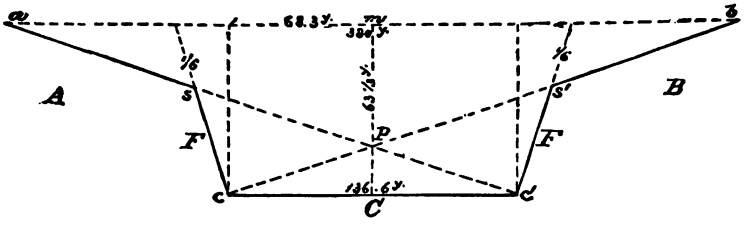
It is plain that a dependency exists between the lengths of faces, flanks, and curtain of a bastion front. The curtain being fixed, and the positions of the flanks selected, the length of the faces are determined; the lengths of the faces and the

positions of the flanks being fixed, the length of curtain is determined, etc. The greatest length of face for a given exterior side will be obtained by combining the least curtain with the least flank, etc.

29. Construction of Trace.—Assume the exterior side to be 380 yards long, and take the curtain to be 136.6 yards in length. The construction is made as follows:

Draw a line as *a b* (Fig. 15) to represent the exterior side. Lay off upon this line a distance, *a b*, equal to 380 yards. Bisect this distance, and from the middle point, *m*, let fall the perpendicular, *m* P.

Fig. 15.



Lay off upon this perpendicular a distance of one-sixth of *a b*, equal to 63.33 yards. Join the point, P, thus determined, with the points *a* and *b*. The magistrals of the faces of the front will coincide in direction with these lines, *a* P and *b* P, thus drawn.

On each side of *m*, and at a distance of 68.3 yards equal to the length of half the curtain from it, on the exterior side, draw straight lines parallel to *m* P, and produce them until they intersect *a* P and *b* P produced. The points of intersection, *c*, *c'*, thus determined, will be the extremities of the magistral of the curtain. Join *c* and *c'* by a straight line, and this will be the magistral of the curtain, and equal in length to 136.6 yards.

Through the extremities, *c*, *c'*, of the curtain, draw the straight lines *c s*, *c' s'*, making an inclination of $\frac{1}{6}$ with the per-

pendicular, as shown in Figure 15; the lines $c\,s$, $c'\,s'$, will be the magistrals of the flanks, and the lines $a\,s$ and $b\,s'$ will be the magistrals of the faces.

30. Nomenclature of Trace.—The lines $a\ s$ and $b\ s'$ are the magistrals of the **faces**; $s\,c$, $s'\,c'$, of the **flanks**; $c\,c'$ is the magistral of the **curtain**; $a\,b$ is the **exterior side**; m **P**, the **perpendicular**; the angles of the bastions, **A** and **B**, at a and b, are termed the **salients**; at s, s', the **shoulder angles**; the angles at c, c', are called the **curtain angles**; the angles **P** a m and **P** b m are known as the **diminished angles**; the lines c **P** b and c' **P** a are called the **lines of defence.**

It will be observed that a second polygon, similar to the circumscribing polygon, can be formed by producing the curtains of the adjacent fronts until they intersect. A side of such polygon is called an **interior side.**

31. Magistral of Ravelin.—A redan is placed on the opposite side of the main ditch in front of the curtain, which is called the demi-lune or **ravelin**. Its magistral is constructed as follows:

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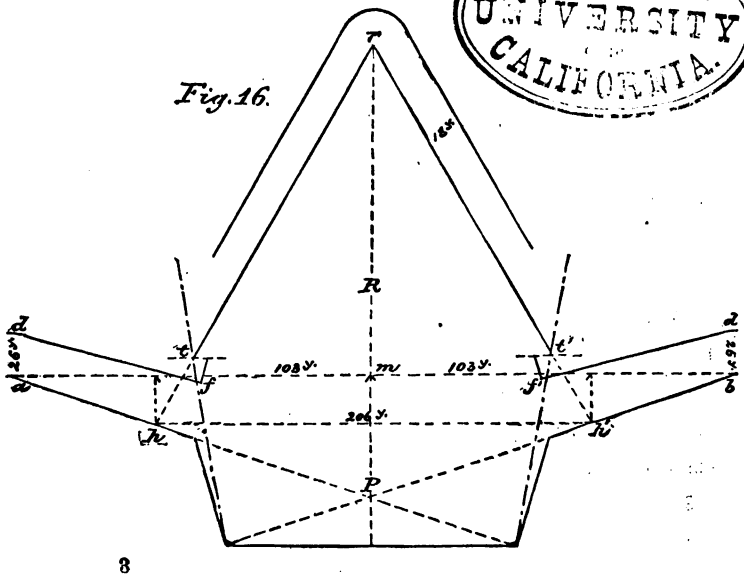
Fig. 16.



Lay off upon the exterior side 103 yards on each side of the perpendicular (Fig. 16), and draw through the extremities two lines parallel to the perpendicular; find the points in which these lines intersect the magistrals of the faces and join them by a straight line, $h h'$; upon this straight line construct an equilateral triangle; the sides $h r$ and $h' r$ of this triangle will be the projections of the magistrals of the faces of the ravelin. The extremities of the magistrals are determined by drawing a line parallel to and eleven yards from the exterior side; the intersections, t and t', of this line with the faces are the extremities of the magistrals of the ravelin.

The ravelin is surrounded by a ditch 18 yards wide. A line drawn parallel to the face and 18 yards from it will be the projection of the magistral of the counterscarp of the ravelin ditch.

32. Magistral of Counterscarp of Main Ditch.—The main ditch is made 26 yards wide at the salients. The magistral of its counterscarp is determined by drawing a right line tangent to an arc with a radius of 26 yards at the salient, and directed upon a point near the interior crest of the opposite shoulder angle. As this latter point is not yet fixed, the magistral may be drawn as follows:

With a (Fig. 16) as a centre, describe an arc of a circle with a radius of 26 yards. Through the point t, the extremity of the face of the ravelin, draw a perpendicular to the face and lay off on it, within the ravelin, a distance of 6.66 yards. Through this point, just determined, let fall a perpendicular upon a tangent to the arc described at the salient, imposing the condition that the point of intersection, f, of these two lines shall lie within the exterior side and 3.33 yards from it. The line, $f d$, thus located will be the projection of the magistral of the counterscarp.

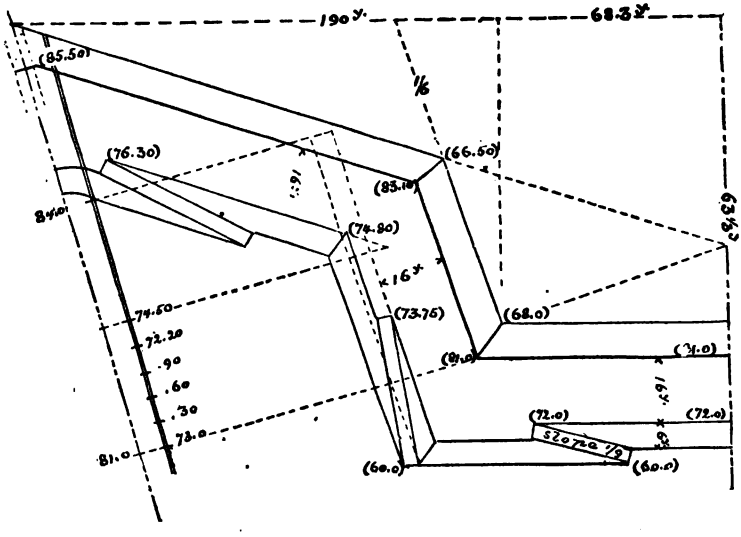
33. Remark.—The magistrals of the faces, flanks, and the curtain have been constructed in plan, but they are not fully

given until their references are known. When the references are determined, the lines are fixed.

The plane of reference is taken below the work, and low enough to avoid the use of negative signs. It is assumed, in this example, to be sixty feet below the plane of site (Fig. 13). This gives the reference of the plane of site to be (60.0).

34. Magistral of Main Work.—The magistral of the main work is composed of the magistrals of the curtain, the flanks and the faces. These lines are not all horizontal, and do not have the same heights above the plane of reference.

Fig. 17.



The magistral of the curtain is made horizontal, and as it is a line of masonry, it is taken so as to be screened from the enemy's view.

A covered way surrounds the main work, and its interior crest is not less than eight feet above the plane of site. If the magistral of the curtain is not placed higher than this above the plane of site, it will be hidden from the enemy's view by the crest of the covered way. Giving it this height,

it will have a reference of (68.0), which determines its position. The bottom of the ditch from the middle of the curtain to its ends, slopes so as to have in that distance a fall of one foot and a half. From the ends of the curtain to the shoulder angles, it slopes as much. The result is to make the magistral of the curtain one foot and a half higher above the bottom of the ditch at the ends than at the middle.

The magistral of the flank is made parallel to the bottom of its ditch, or slopes from the curtain to the shoulder angle, one foot and a half. The references of this magistral are (68.0) at the curtain angle, and (66.50) at the shoulder angle. The projection and references being given this line is fixed.

The magistral of the face is horizontal, and at the shoulder angle has a reference of (66.50), or the same as the flank at that point. The projection and this reference fix the position of this line.

These lines fixed, the magistrals of the main work are fully given.

35. Interior Crest of the Main Work.—The interior crest of the curtain of the main work is parallel to its magistral. The interior crests of the flanks and faces are not horizontal, nor are they parallel to their magistrals, but for each bastion are contained in a plane which has an upward slope from the curtain to the salient.

To construct the interior crest of the curtain, it is only necessary to know its horizontal distance from the magistral, and draw a line parallel to and at this distance from the magistral to determine its position.

The horizontal distance between these two lines is composed of the thickness of the parapet, the width of the base of the exterior slope and the width of berme. The thickness of parapet is 24′.0; the width of base of the exterior slope, since the interior crest has a command over its magistral of 13′.0, is 9′.0; the width of berme is 1′.5. These distances

added together give 34′.5 = 11.5 yards as the horizontal distance between the lines. A line, therefore, drawn parallel to the magistral and 11.5 yards from it (Fig. 17), is the projection of the interior crest. Giving this line the reference (81.0) fixes its position and determines the position of the interior crest of the curtain.

It is limited, or its extremities are found, by drawing lines bisecting the curtain angles. The intersections of these bisecting lines with the curtain determine the extremities of the interior crest of the curtain.

The extremities of the interior crest of the curtain are points of the interior crests of the flanks. A second point for each will with these fix the position of the flanks.

The interior crests of the flanks and faces of a bastion lie in a plane containing the extremities of its adjacent curtains and passing 4.5 feet above the salient of the bastion.

The salient of a bastion is usually blunted, by cutting off a part of it to allow a fire in the direction of its **capital**, or right line bisecting the angle at the salient. This blunted portion is called a **pan-coupé**. The interior crest of the pan-coupé is horizontal and perpendicular to the capital. Its length should be at least sufficient to give room for one gun.

Assuming the least length for one gun to be 4.33 yards, let two lines be drawn on each side of the capital of the bastion, parallel to and 2.16 yards from it (Fig. 17). These lines will limit the length of the pan-coupé. The extremity of the pan-coupé is a point of the interior crest of the face. Since this pan-coupé is taken four feet and a half higher than the curtain and is horizontal, this point of the interior crest of the face will have a reference of (85.50); or, it will be nineteen feet above the magistral of the face, which has a reference of (66.50). The horizontal distance, therefore, from this point to the magistral is (24′ + 15′ + 1′.5) = 40′.5 = 13.5 yards. Draw a line parallel to the magistral of the face and

13.5 yards from it; the point at which this line cuts the line parallel to and 2.16 yards from the capital, will be the point of the interior crest of the face, which has a reference of (85.50).

This point is also a point of the pan-coupé; a line drawn through it perpendicular to the capital of the bastion is the interior crest of the pan-coupé.

The interior crest of the pan-coupé is a horizontal line of the plane containing the faces and flanks of the bastion. This line and the extremity of the curtain determine this plane, and from them its scale of slope can be constructed.

One point of the interior crest of the face has already been determined. It is an easy thing to determine a second point and to draw the line through them. For example, suppose it be required to determine that point of the face which has a reference (84.0). The reference of the magistral is (66.50). The required point is, therefore, 17′.5 higher than the magistral. Its horizontal distance from the magistral is (24′. + 13′.5 + 1′.5) = 39′.0 = 13 yards. The projection of the required point must, therefore, be on a right line parallel to the magistral and 13 yards from it, and must be on the horizontal of the plane whose reference is (84.0). Draw these two lines; their intersection will be the point required. Having two points of it, the interior crest is determined by drawing a straight line through them. It is terminated at one end by its intersection with the pan-coupé, and at the other by its intersection with a line bisecting the shoulder angle of the magistral.

The interior crest of the flank is determined by joining the extremity of the curtain with the extremity of the face at the shoulder angle by a right line. The determination of the extremities of the faces and of the curtain, by bisecting the shoulder and curtain angles, is not rigorously accurate; neither are the determinations of the interior crests of the faces

exactly correct. But the results obtained by the methods used differ so slightly from the rigorously accurate ones that the differences, in the example, would scarcely be appreciable.

The magistral and interior crest of the main work having been constructed, the remaining lines of the parapet are easily drawn by using the dimensions assumed for the profile.

36. Terre-plein of Main Work.—The terre-plein, in the example, is made 16.0 yards wide, and placed *eight* feet below the interior crest.

The terre-plein of the curtain is given an inclination to the rear of $\frac{1}{48}$ for drainage. This slope fixes the crest of the rampart slope, and makes its reference (72.0). (Fig. 17.)

The terre-plein of the bastion is parallel to the interior crests, and lies eight feet below the plane containing the interior crests of the faces and flanks. This terre-plein slopes, therefore, 4.50 feet from the salient to the curtain angle, and the scale of slope of the plane of the faces may be used for its scale by subtracting eight feet from the corresponding divisions upon it.

The terre-plein is reached by ramps or by flights of steps connecting it with the parade. Two ramps are used for the curtain, one for the flank, and one for the face. More are used when necessary.

The ramps should be large enough for the passage of the artillery to be used in the defence of the work, and should have easy slopes. In the trace under consideration the ramps are made 4.33 yards wide, and have a slope of $\frac{1}{9}$.

To construct the plan of a ramp, a point of the foot of the rampart slope is assumed as the intersection of the foot of the ramp with this slope; through this assumed point a right line is drawn that shall lie in the plane of the rampart slope, and make an inclination of $\frac{1}{9}$ with the plane of site; the point where this line pierces the terre-plein is found, and

the intersection of the plane of the ramp with the terre-plein is determined; the width of the ramp is then laid off and the other side of the ramp is determined.

37. Remarks upon the Construction of the Trace.—The length of the curtain and the direction of the faces were first assumed, and then the positions of the flanks and the lengths of the faces fixed. It is evident that similar results could be obtained if the faces and direction of the flanks were assumed and the curtain determined.

The dimensions of the profile being assumed, the least length of curtain was determined. This length of curtain obtained, it became necessary to fix upon the length of the exterior side. A length was given to this side which would allow the counterscarp of the bastion salient to be in close range of the artillery of the flank, and also within the effective range of small-arms. A length of 380 yards for the exterior side places the covered way opposite to the salient of the bastion, about 300 yards from the flank which has a fire upon it. This length of 380 yards would at the present time be about the least length used.

The magistral of the face is drawn through a point upon the perpendicular of the front and at a distance from the exterior side of one-sixth the latter's length. The object of this construction is to give room enough to have flanks of sufficient length to be armed with batteries equal to, or more powerful, than those that an enemy can bring to counterbatter them.

By this construction the length of curtain, of the faces, and the direction of the flanks are so combined as to give an efficient flanking of the entire scarp from the work itself, and to give a strong cross fire on all the ground in front.

The curtain is horizontal, while the interior crests of the faces and flanks are inclined. The object of making the latter inclined is to afford a better protection for the troops

and guns on the terre-plein of the bastion from an enemy's fire coming over the salient. A shot grazing the salient and following the general direction of one of the faces would reach the terre-plein, when inclined, further from the salient than it would were it made horizontal. The inclination of the terre-plein is the same as that of its interior crests, or is 4'.5 lower at the extremities of the flanks than it is at the salient.

This height of 4'.5 given to the salient of the interior crest of the bastion above the interior crest of the curtain, is in general the greatest height it can have. If it were made higher, the terre-plein of the bastion would ordinarily be exposed to a reverse view of the enemy from points exterior to the work. The terre-plein is taken eight feet below the interior crest. This distance is assumed to be the least one that can be used, and is taken in the front under consideration to give a definite distance to be employed in the problems of construction.

OUTWORKS.

38. The Object of Outworks.—The main work is one of the defensive lines adopted for the defence of a given position. If the defence is to be an active one, this defensive line should be so arranged that all movements of the defenders intended to be offensive, shall not be hindered or impeded in any way by the arrangement of the line itself or its communications.

A defensive line strengthened by a fortification constructed according to the trace as far as described, is suitable only for a passive defence, since the garrison upon emerging from the main ditch would be immediately exposed to an enemy's fire before the formations necessary to advance could be made. Moreover, supposing an advance to have been made, and a retreat to become necessary, it might be possible that the enemy pursuing vigorously, might be able to enter the work

simultaneously with the garrison, and obtain possession of the work itself. A line defended by the main work alone is expected, therefore, to be defended passively.

To allow an active defence, outlets must be provided, and communications across the ditch and with the exterior arranged. Defensive works are placed beyond the main ditch to mask these outlets and communications. These works are placed in **close defensive relations** with the main work, and are intended by their resistance to prolong the defence of the main work, as well as to facilitate offensive operations upon the part of the garrison. Works so placed are termed **outworks.** (Art. 22.)

39. General Conditions.—There are certain conditions which outworks should satisfy to make them effective. These conditions may be stated as follows:

1. *The outworks must be safe against an open assault;*

2. *The scarps should be well flanked; and, when possible, from the main work;*

3. *The outworks in advance should be commanded by those in their rear; and, when this is impracticable, the outworks in rear should be defiladed from those in front of them;*

4. *The outworks should be placed so as to require an assailant to gain possession of those in advance before he can occupy those in rear of them;*

5. *The communications between the outworks and the main work should be convenient and well protected; and the communications of any outwork should not be dependent upon those of the others.*

The **first** of these conditions is satisfied by means of a wet ditch, or a scarp wall. A wall high enough to compel the assailant to use ladders to climb over it is considered safe against an open assault. In the constructions to be explained, the height of 13.0 feet is assumed as the least height to be given to a scarp wall of any outwork.

The **second** of these conditions is satisfied by giving such

positions to the ditches of the outworks that they can be swept by the fire of works in their rear.

The other conditions can be better explained by a description of the outworks and of the methods used in their construction.

40. Salient and Re-entering Places-of-arms. — The counterscarps of the ravelin and the main ditch are enveloped by a covered way, the crest of which has a command of not less than *ten* feet, and is nearly parallel to these counterscarps. This crest is a right line in front of the bastion, but is a crémaillère line in front of the faces of the ravelin. Its salient opposite the ravelin has a command of ten feet and a half, or a reference (70.50).

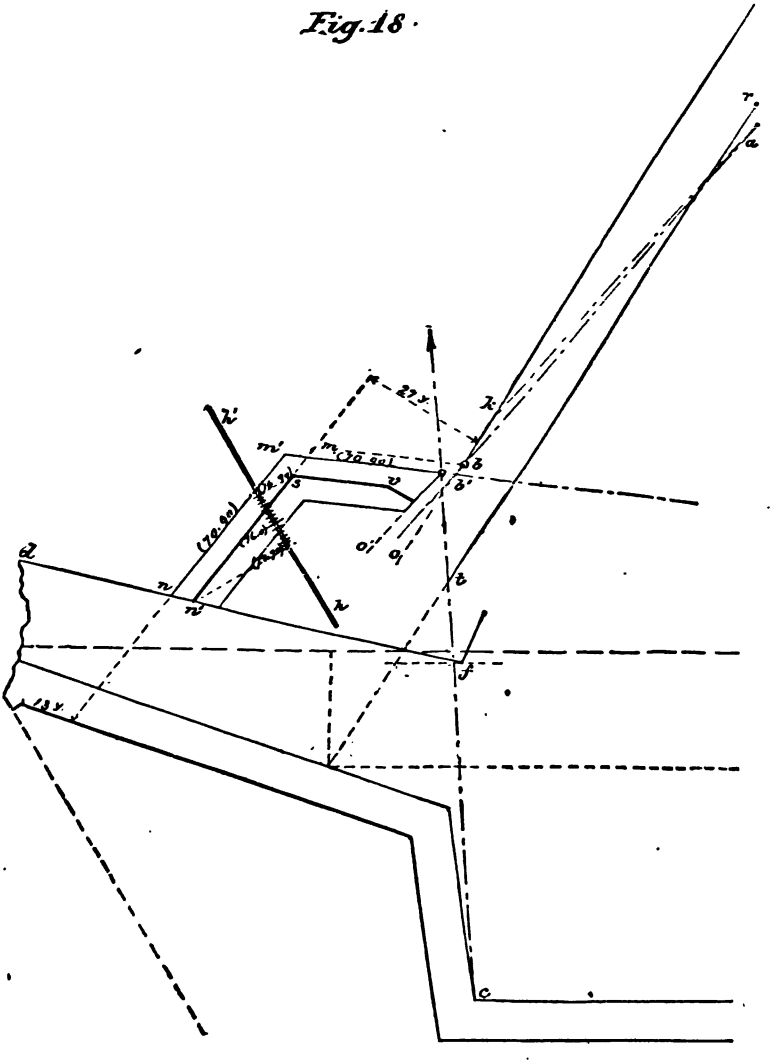
The directions given to the crest of the covered way are such as to form salient angles opposite to the salients of the bastion and of the ravelin. The spaces within these salient angles receive the name of **salient places-of-arms.**

The crests, if produced until they intersect within the angle made by the counterscarp of the bastion with that of the ravelin, would form a re-entrant angle opposite the extremity of the ravelin face. The crests are not produced so far, but are made to change direction before this point of intersection would be reached, and to form a salient angle within the re-entering, or angle, of the two counterscarps. This enlargement of the covered way, by this change of direction, is called a **re-entering place-of-arms.** The re-entering place-of-arms, in the modern front, is made large enough to have a strong redoubt placed in it, and still leave room in the place-of-arms for troops to be assembled for the purpose of making sorties.

41. Redoubt of the Re-entering Place-of-arms.—The construction of the redoubt will be given first, as it will facilitate the explanation of other constructions by taking it first in order. The magistral and interior crest of the redoubt

are shown in Figure 18. The construction of the magistral is as follows: A straight line is drawn through the extremity,

Fig. 18.



c, of the curtain and the extremity, *t*, of the ravelin face. The condition is imposed that the inner end of the magistral of the redoubt shall lie on this line prolonged. A point, *a*, is

taken within the ravelin, on the perpendicular of the front, and five yards from the salient, *r*, of the ravelin. Through a point, as *b*, assumed upon the ravelin counterscarp, and the point *a* draw a right line. Draw through the point *b* a right line, making an angle of 60° with the line *a b o*. Within the angle *m b o*, a line is drawn parallel to and 4.33 yards from the line *m b*; also, one parallel to *b o* and 2.0 yards distant. If these two lines intersect on the line *c t* produced, the point of intersection will be the extremity, and the line *m′ b′* will be the projection of the magistral of the face of the redoubt next to the ravelin.

If the intersection is not upon the line *c t*, other points, as *k*, etc., should be assumed on the counterscarp of the ravelin, and similar constructions made until the condition imposed is satisfied.

Knowing one extremity, it will be necessary to determine the other extremity, *m′*, to have the projection complete. Having found this extremity, *m′*, the magistral of the other face is projected in a line passing through *m′* and a point of the interior crest of the bastion face 13.0 yards from the pan-coupé. This direction is given to this face so as to allow its ditch to be swept by the fire of the bastion. To determine *m′*, it will be necessary to consider first the length of the interior crest of the face, and determine the position of its salient, *s*.

The besiegers upon reaching the covered way around the salient of the ravelin would proceed to establish breaching batteries on its glacis to fire upon the ravelin, and counter-batteries to fire along the ravelin ditch upon the faces of the bastions.

The depth of a battery, the thickness of its parapet, and the width of the covered way in its front added together would make a distance of twenty-seven yards or more. If the interior crest of the face of the redoubt looking in the direc-

tion of the ravelin salient be made long enough to have its salient at the distance of 27.0 yards from the ravelin counterscarp, the entire flank of the batteries established upon the glacis of the salient place-of-arms can be swept by the fire of this face. The projection, s, of the salient is therefore taken on a line drawn parallel to the ravelin counterscarp and 27.0 yards from it.

The interior crest of this redoubt should be kept as low as possible, so as not to interfere any more than can be helped with the fire of the main work. This condition requires the interior crest of the redoubt to be lower than the interior crests of the adjacent ravelins, and makes it necessary to defilade the redoubt from the salients of these ravelins. This defilade is effected by placing the interior crest of the redoubt in a plane, the scale of slope of which is parallel to the capital of the bastion, and the inclination is such that the salient, s, shall be two feet higher than the extremity, n', of the face directed upon the bastion.

To keep the interior crest as low as possible, and to get a scarp wall 13.0 feet high, the parapet of the extremity, n', is made without an exterior slope. This arrangement of the parapet at the extremity gives the width of the base of the exterior slope of the parapet at the salient to be two feet, and makes the horizontal distance of s from the magistral $m'b'$ equal to $(24' + 2' + 1'.5) = 27'.5 = 9.16$ yards.

The projection of the salient, s, is made to lie upon a line parallel to and 27.0 yards from the ravelin counterscarp; it must be 9.16 yards from the magistral $m'b'$. The intersection of a line drawn parallel to this magistral, $m'b'$ and 9.16 yards from it, with a line parallel to and 27.0 yards from the ravelin counterscarp, will be the projection of the salient, s.

Through the point of the interior crest of the bastion face 13.0 yards from its salient, a line is drawn tangent to an arc described with s as a centre, and a radius of 9.16 yards. This

tangent line will be the indefinite projection of the magistral of the face of the redoubt, and its intersection with the magistral, $m' b'$, determines the salient of the magistral. The other extremity of the magistral is at n, where the tangent line intersects the bastion counterscarp.

The magistral of the scarp of the redoubt is horizontal, and is masked by the crest of the re-entering place-of-arms by being placed one foot and one-tenth lower than the crest of the salient of this place-of-arms. The crest of this salient is made one foot and a half higher than that of the salient place-of-arms, or has a reference of (72.0), the reference of the crest of the salient place-of-arms being (70.50). This gives the magistral the reference (70.90).

The interior crest of the redoubt at its salient is placed 6.0 feet above the magistral, which gives it a reference (76.90). This fixes the reference of the extremity, n', at (74.90). The horizontal distance between n' and the magistral is 8.5 yards. The extremity, n', is therefore determined by finding a point on the counterscarp, $d\ f$, which is 8.5 yards from the line $m' n$. The interior crest of the face next to the ravelin has one point, s, given. A second point is found by the method already used. (Art. 35.) This face changes the direction of its interior crest at a point which is 6.0 yards from the line passing through o' and the extremity of the magistral; the interior crest for this distance of 6.0 yards being made perpendicular to the line drawn through o'.

The terre-plein is made parallel to the plane of the interior crest and placed eight feet below it. Instead of a rampart slope, the terre-plein is connected with the level below by a masonry wall. Walls of this kind are termed **gorge** walls. This wall has the same batter as that given to the others, which in this case is $\frac{24}{1}$.

42. Remarks upon the Redoubt.—The masonry of the scarp wall of the curtain is masked by the ravelin from the

fire of breaching batteries that may be established upon the ravelin glacis.

If there is no redoubt in the re-entering place-of-arms, the masonry of the curtain would be exposed to the fire of breaching batteries placed upon the glacis of the re-entrant, unless a mask is interposed between the glacis and the masonry.

By placing the redoubt in the position described in the construction of its magistral, these two works, the ravelin and the redoubt, completely mask the masonry of the curtain from the fires above mentioned.

It is a common thing in the art of fortification to combine two or more works for such a purpose, and it illustrates a principle which may be stated as follows:

"Where a given line is partially covered by an existing mass from a particular field of fire, *to interpose a second mass which, with the first, will completely mask the line.*"

The primary object of a permanent redoubt in the re-entering place-of-arms is its use as a mask. The next object sought for in its construction is to add to its obstructive value strong defensive qualities.

These defensive qualities are obtained by giving to the redoubt a parapet, and arranging its lines so that the fire from them shall sweep the glacis in front of the ravelin, and in front of the bastion salient.

The faces are directed so as to allow the ditches to be swept by the fire of the works in rear. The small flank of 6.0 yards made perpendicular to the line $o'\ b'$ is for the purpose of obtaining a reverse fire upon that part of the ravelin where a breach would be probably made in its face.

The terre-plein is defiladed from the salients of the ravelins which command it. It is given its least width because the work is to be defended only by infantry. It is seen that, besides its use to mask the masonry of the curtain, it adds to

the efficiency of the covered way by its sweeping fires along the glacis.

In the construction of the magistral a point was assumed on the perpendicular of the front, at a distance of five yards from the ravelin salient. This line, *a b*, drawn through *a*, limits the field of fire to which *b* would be exposed from an enemy on the glacis of the ravelin. The parapet of the ravelin would intercept all fire from the glacis below this line.

An angle of 60° is given to the salient point, *b'*, as this is the least angle admissible in masonry constructions compatible with strength. This least angle is also used for the purpose of bringing the salient, *m'*, as far within the re-entering as practicable. The point *b'* is taken a distance of 4.33 yards from *b* in one direction, and 2.0 yards in another. This distance of 4.33 yards is the width of the bottom of the ditch of the redoubt. The distance of 2.0 yards is the width of the stairs by means of which a person at the foot of the gorge wall can ascend to the bottom of the redoubt ditch.

This point *b* is the intersection of the counterscarp wall of the ravelin with that of the redoubt ditch, and is raised high enough to cover a man standing on the top step from a fire coming from the glacis of the ravelin salient.

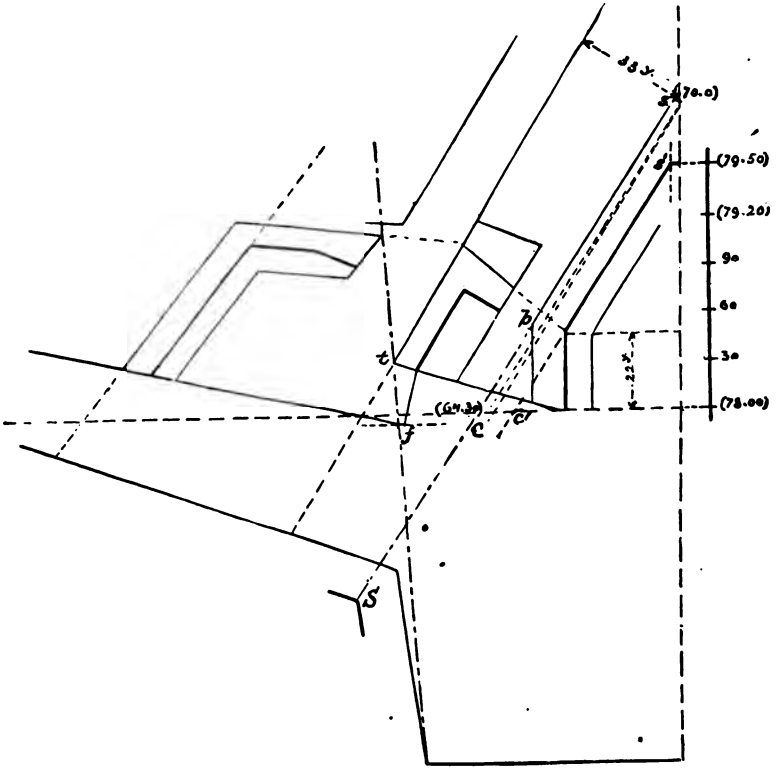
Access to the terre-plein from the space in rear of the gorge wall is obtained by a postern and winding stairs under the parapet.

43. Redoubt in the Ravelin.—A permanent redoubt is built in the ravelin to add to the latter's strength. Its trace is constructed as follows:

The salient, *s* (Fig. 19), of the magistral of the ravelin redoubt is on the perpendicular of the front, and at that point which is 33 yards from the magistral of the ravelin. This point having been determined, the projection of the magistral of the face, *s b*, is found by drawing a right line from the point *s* to the shoulder angle, S, of the interior crest

of the bastion. To find the references, that of the point *s* is first determined, and then the magistral is given a slope such that when produced, the point *c* projected at the intersection of the magistral with the exterior side shall be 5.70 feet below the salient, *s*.

Fig 19.



The magistral of the redoubt at its salient is placed on a level, or below the terre-plein of the ravelin. In this case, it is taken at the same height as the terre-plein.

The terre-plein is made, as in the case of all the others, eight feet below the interior crest. The interior crest of the ravelin should have a command over its covered way of at

least six feet, and be commanded by the interior crest of the curtain of the main work by at least three feet. The reference of the interior crest must therefore be between (70.50), the reference of the ravelin covered way, and (81.0), the reference of the curtain. In this front, the reference is taken to be (78.0), or three feet below the curtain. This fixes the reference of *s* at (70.0).

The reference of the point projected at the intersection of the projection of the magistral with the exterior side, is 5'.70 lower, or (64.30). The reference of two points of the line and its projection being known, the line is fully determined.

To draw the interior crest of this face, the reference of the salient must be first fixed. The salient is made blunted, and is made to command the ravelin salient. The interior crest of the ravelin salient has been given a reference (78.0), and the interior crest of curtain a reference (81.0). The salient of the redoubt is placed half-way between them, or given a reference of (79.50). The pan-coupé is horizontal, has therefore a reference of (79.50,) and is made of the same dimensions as that of the bastion.

The interior crest of this redoubt is composed of two faces and two flanks, the latter being parallel to the perpendicular of the front. The crest is held in a plane whose scale of slope is parallel to the perpendicular, and whose inclination is such as to place the interior crest of the flanks at the extremities one foot and a half below the pan-coupé. The reference of the pan-coupé is (79.50), and of the extremities of the flanks (78.0). From these data the scale of slope is constructed. The interior crest of the face is determined by finding two points by a method similar to that used in Art. 35, and drawing a straight line through them.

In finding the points of the interior crest of the face of the bastion, the distances of the points were laid off from the magistral, it being a horizontal line. In this case the magis-

tral is inclined, and it is necessary to use an auxiliary line from which the distances of the points can be measured.

To explain how such an auxiliary line is drawn and used, the construction of the interior crest of the face of the redoubt will be given.

The magistral of the face has a reference of (70.0) at the salient, and (64.30) at the point of intersection with the exterior side. The foot of the exterior slope is a line parallel to the magistral, and one foot and a half from it. Suppose a line drawn parallel to the magistral, and one foot and a half from it, on the side of the magistral next to the parapet. Give this line at the point of intersection with the perpendicular a reference of (70.0), and find the point whose reference is (64.30); this line will be the foot of the exterior slope. Take this latter point (64.30) as a centre and describe an arc with a radius of $5'.70 = 1.90$ yards; through the point (70.0) draw a line tangent to this arc, and on the side next to the parapet give this line a reference of (70.0), and it will be a horizontal line of the exterior slope. This line can be used to measure the horizontal distances from it to points of the interior crest, as follows:

The pan-coupé is horizontal, and has a reference of (79.50). The intersection of the interior crests of the face and pan-coupé is one point of the face. Its horizontal distance from the line (70.0) is $(24' + 5'.50) = 29'.50 = 9.83$ yards. The point upon the line limiting the length of the pan-coupé and 9.83 yards from the line (70.0) is the point of the interior crest of the face, with a reference of (79.50).

A second point is obtained as follows: If the face were produced until it intersected the exterior side, this point of intersection, c', would have a reference of (78.0), since it lies in the plane whose scale of slope has been constructed. The horizontal distance of this point from the horizontal line (70.0) is $(24' + 4') = 28' = 9.33$ yards. That point on the exterior

side which is 9.33 yards from the line (70.0), will be a point of the interior crest of the face produced. A line joining the two points, (79.50) and (78.0), will be the projection of the interior crest of the face.

The shoulder angle of the interior crest is determined by drawing a straight line parallel to the exterior side and 22 yards from it. The intersection of this line with the interior crest of the face fixes the position of the shoulder angle, and fixes the length of the faces. The interior crest of the flank is determined by drawing from the shoulder angle a right line parallel to the perpendicular, and terminating it at its point of intersection with the exterior side.

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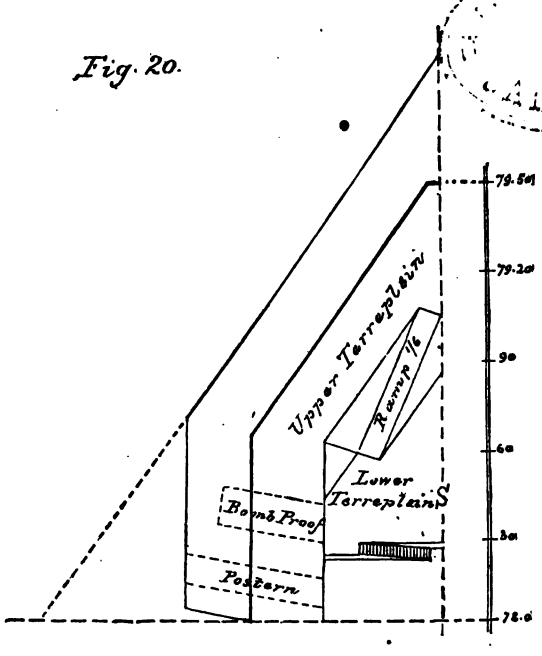
Fig. 20.



The magistral of the scarp of the flank is horizontal, and terminates upon a right line joining the extremity of the interior crest of the flank, and the extremity, *t*, of the magistral of the face of the ravelin.

Parallel to the interior crest, and eight feet below its plane, a terre-plein is made. The terre-plein of the face is made 8.66 yards wide; that of the flank is 11.0 yards wide. This latter width is to allow cannon to be used in the flanks.

The remaining interior space, S (Fig. 20), is made into another terre-plein, called the **lower**, to distinguish it from the **upper** one. The lower terre-plein is thirteen feet below the upper one, and held parallel to it. The upper terre-plein is connected with the lower one by a slope of $\frac{2}{3}$, excepting a length of 14.0 yards from the gorge, for which a masonry wall is used. Communication between the terre-pleins is by two ramps, each 3.33 yards wide, and with slopes of $\frac{1}{6}$.

The reference of the upper terre-plein at the gorge is (70.0); the reference of the lower one, if the plane of its surface be produced to the gorge, is thirteen feet below that of the upper, or (57.0). This reference places the lower terre-plein 20'.50 above the bottom of the main ditch, which at this part has a reference of (36.50). The lower terre-plein is not extended the full distance to the exterior side like the upper one, but for a distance of about 6.0 yards is excavated to the bottom of the main ditch.

Access to the lower terre-plein from the main ditch is obtained by a flight of steps (Fig. 20). A bomb-proof shelter is built under the parapet of the flank with its entrance opening upon the lower terre-plein.

Access to the ditch of the redoubt from the main ditch is had by a postern in the flank. The bottom of the redoubt ditch is parallel to the magistral of the redoubt, and 16'.50 below it. The reference of the bottom of the ditch at the salient is therefore (53.50), and at the shoulder angle about (49.50), as the magistral has a fall of about four feet for that distance.

44. Remarks upon the Ravelin Redoubt.—The face of the redoubt is directed upon the shoulder angle of the bastion

for the purpose of having its ditch swept by the fire of the bastion.

The flank is made parallel to the perpendicular to obtain a reverse fire on the breach that might be made in the bastion face. Its length and the width of its terre-plein are estimated upon the probable use of three cannon in each flank.

The interior crest of the redoubt slopes one foot and a half from the salient to the gorge. This inclination of the crest defilades the redoubt from any fire coming from the ravelin salient.

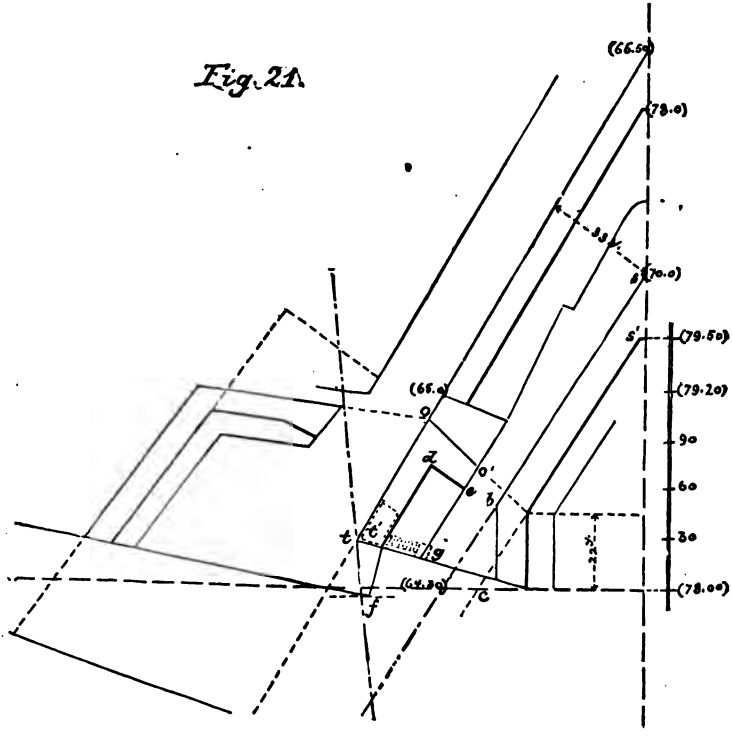
The effect of placing the magistral of the redoubt upon the same level, or below that of the ravelin terre-plein, is to compel an enemy in possession of the ravelin salient to lower his batteries, or to use mines to breach the redoubt scarp wall. Both of these operations require an extra amount of labor and considerable time for execution.

As it is desirable to have the redoubt as capacious as practicable, the salient of the magistral is placed within 33 yards of the magistral of the ravelin, and the scarp wall is made 16'.5 high. The distance of 33 yards is the least that will allow room for the parapet and terre-plein of the ravelin, and for the width of the redoubt ditch. If the scarp wall were made lower, it would have the effect of throwing the interior crest farther back, and of contracting the interior space of the redoubt.

The redoubt strengthens the ravelin by its close musketry fire, and forces an enemy in possession of the ravelin to take the redoubt before he could assault successfully a breach made in the face of the bastion, as such a breach would be seen in reverse from the flanks of the redoubt.

45. The Ravelin.—The construction used for obtaining the projection of the magistral of the ravelin is described in Art. 31. It will be necessary to determine the references of the line to fix its position.

The magistral of the ravelin, like those of other outworks, is lower than the crest of the covered way in front of it. The



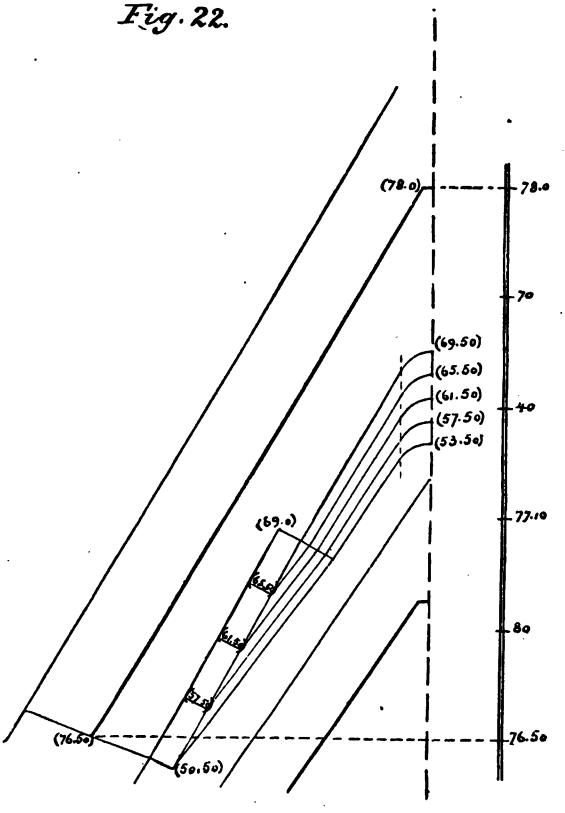
salient of this magistral, in this particular example, is taken four feet below the crest of the salient place-of-arms. The salient of the salient place-of-arms was given a command of 10.50 feet over the plane of site. This fixes the salient of the ravelin magistral at 6.50 feet above the plane of site, and makes its reference (66.50), the same as that given to the magistral of the bastion face.

The magistral of the ravelin is not horizontal, but slopes so as to have a fall of one foot and a half from its salient to a point opposite the redoubt of the re-entering place-of-arms. The position of this latter point is obtained by producing the

magistral of the redoubt of the re-entering place-of-arms until it intersects the projection of the ravelin magistral. From this point of intersection, a distance of 6.66 yards is laid off in the direction of the salient. The extremity of this distance is the point of the magistral which has the reference (65.0).

The references (66.50) and (65.0) determine the positions of

Fig. 22.



two points, and fix the position of the magistral between them. The remainder of the magistral is made horizontal.

The scarp wall of the ravelin is made 22.5 feet high. The interior crest of the face is parallel to its magistral, and is

made with a pan-coupé at the salient. This pan-coupé has a reference of (78.0), as stated in Art. 43.

The terre-plein is parallel to the interior crest, placed eight feet below it, and is made 11.0 yards wide. A ramp, 3.33 yards wide, with a slope of $\frac{1}{6}$, and placed as shown in Figure 22, affords communication between the terre-plein of the ravelin and the bottom of the ditch of the ravelin redoubt. The side of the ramp next to the redoubt is joined to the bottom of the ditch by an earthen slope of $\frac{1}{4}$.

The terre-plein at the salient is connected with the bottom of the ditch of the redoubt by a slope of earth of curved shape (Fig. 22). This curved slope is made so as to leave a width of 4.33 yards between its foot and the scarp of the redoubt. The top of the slope is made tangent to the edges of the terre-plein. The terre-plein from the ramp to this curved part is connected with the bottom of the ditch of the redoubt by a slope of earth nearly a plane surface, but in reality a warped surface generated by moving a right line touching the earthen slope of the ramp and the curved slope at the salient. It will be seen that the inclination of the curved slope may be made $\frac{1}{2}$, or about that, and not encroach too much upon the ravelin terre-plein at the salient. By this construction, the curved portion receives so gentle a slope that it may be used as a ramp for infantry.

46. Remarks upon the Ravelin.—The primary use of the ravelin was to serve as a cover for the principal entrance of the main work. It was soon enlarged to give protection to the scarp walls of the curtain and shoulder angles of the main work from the fires of breaching batteries of an enemy, and arranged to bring cross fires on the salients of the bastions.

From its strength, it delays the advance of the besieger upon the main work, and forces him to attack the ravelin first. It possesses the advantage of intercepting the enfilading fires

of an enemy upon the faces of the bastions of the adjacent fronts, whenever the angles of the circumscribing polygon are very obtuse.

To obtain these advantages of cross fires and intercepts of enfilading ones, the salient angle of the ravelin is made 60°, the least angle admissible. This angle gives the longest faces for the same base, and therefore the largest ravelin that can be used.

The ravelin is commanded by the curtain, but nevertheless it deprives the curtain of its fire on the ground in front.

The extremity of the ravelin face is terminated at the distance of 11.0 yards from the exterior side, to allow room for a passage-way along the wall that holds up the end of the face, and to unmask the fire of the flank of the ravelin redoubt upon the bastion face where a breach may be made.

The ditch is made 18.0 yards wide, and revetted with a scarp wall 22.5 feet high. This secures the ravelin against open assault, although a revetment wall is less needed for this outwork than for any of the others, since an enemy, even if successful in carrying it by assault, could hardly maintain possession of it unless his trenches were very close to the work.

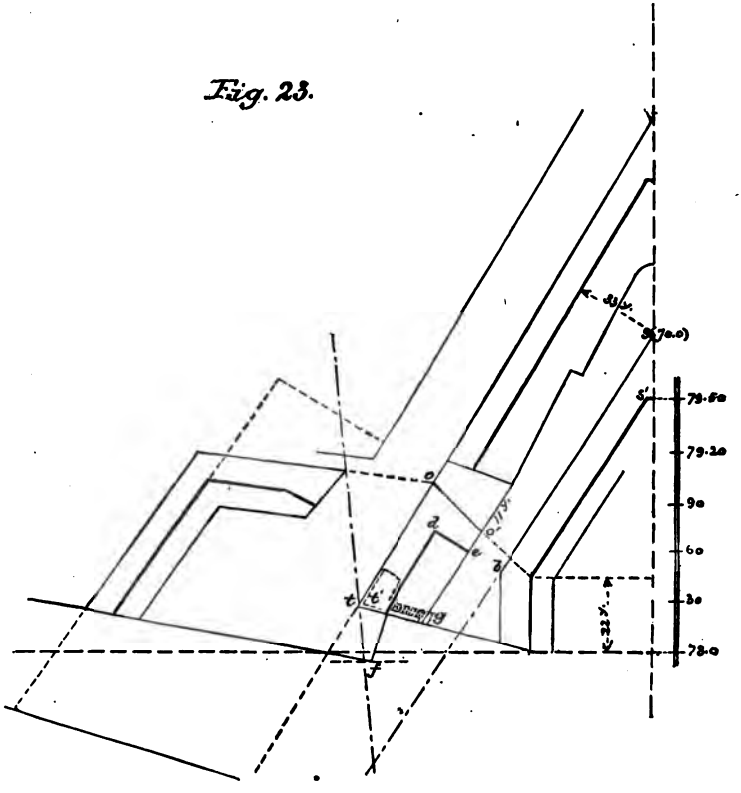
The terre-plein is made only 11.0 yards wide, so as to allow room for the redoubt, and to give additional trouble to an enemy in establishing a battery on it when in possession of the work. The faces of the ravelin are exposed to enfilade fire, and must be provided with traverses or other devices to screen them from this fire.

The glacis of the covered way at the ravelin salient forms a ridge that is favorable for the enemy, as it screens the enemy's trenches on one side of it from the fire of works on the opposite side.

The ravelin in this front is in the shape of a redan. It is sometimes made in the shape of a lunette. A ravelin of the latter form is usually called a **detached bastion.**

47. Cut in the Ravelin Face.—If the parapet and terreplein of the ravelin were carried out continuously from the salient to the extremity of the face, an enemy obtaining possession of the ravelin would very quickly drive the defenders out of the redoubt of the re-entering place-of-arms. To guard against this engineers usually make a cut in the

Fig. 23.



face, isolating the portion of the face that sees this redoubt in reverse from the rest of the ravelin. A parapet is made in the rear of this cut from which a fire can be brought upon the ravelin terreplein. The cut is revetted and given a height of scarp sufficient to secure the parapet in its rear from open assault.

The construction of the cut and of the parapet is as follows:

The magistral of the redoubt of the re-entering place-of-arms is produced until it intersects the magistral of the ravelin face; this point of intersection is joined by a straight line to the shoulder angle of the interior crest of the ravelin redoubt (Fig. 23); this line thus drawn is the indefinite projection of the magistral of the scarp of the cut. The inner end, o', of this magistral is determined by drawing a line parallel to the magistral of the face of the ravelin redoubt and ten yards from it; the intersection, o', of this parallel line with $o\ o'$ is the projection of the inner end, and the line $o\ o'$ is the projection of the magistral of the scarp.

The counterscarp of the cut is constructed as follows:

Lay off from o on the magistral of the ravelin face a distance of 6.66 yards; this is one point of the magistral of the counterscarp in projection; lay off from o' on the line drawn parallel to the magistral of the redoubt a distance of 11.0 yards; this is another point of the projection of the counterscarp; join the two points by a right line, and this is the projection of the magistral of the counterscarp of the cut.

The inner end of the cut is held up by a wall that is in prolongation of the line $g\ o'$; the outer end is on the prolongation of the scarp wall of the ravelin, which is cut down the necessary distance for this width of 6.66 yards.

The parapet behind the cut has its interior crest, $d\ e$, horizontal. It must command the ravelin, and is therefore given a reference of (79.50), the same as that of the salient of the ravelin redoubt. To make this parapet safe from assault it must have a scarp wall of thirteen feet. The interior crest must therefore be at least seventeen feet above the bottom of the cut. The point e of the interior crest has a reference of (79.50), and if the parapet has no exterior slope at this section, the top of the scarp wall of the cut at o' will be four feet lower, or have a reference of (75.50). This point o' is 13.0

feet above the bottom of the cut (to give the least scarp wall), which gives to the inner end of the cut a reference of (62.50). The bottom of the redoubt ditch at the cut has a reference of (50.50) (Fig. 22). The inner end of the cut is therefore twelve feet above the bottom of the redoubt ditch, and thirteen feet below the magistral of the scarp of the cut.

The bottom of the cut is not made horizontal, but slopes from the inner to the outer end, so as to have a fall of 4.80 feet in that distance. This gives a reference of (57.70) for the outer end, and places this outer end about fifteen feet above the bottom of the ravelin ditch. The magistral of the scarp of the cut is parallel to the bottom of the cut, and therefore has a reference at *o* of (70.70). The counterscarp is a profile wall holding up the parapet and terre-plein of the end of the ravelin face at this place.

The parapet behind the cut is made 24.0 feet thick. Its interior crest is determined by finding the horizontal distances of the points *d* and *e* from the line *o o'*, and drawing a line through them at that distance from the magistral. No exterior slope is given to the parapet in the section at *e*, as before stated.

The magistral of the ravelin from the cut to the extremity, *t*, is horizontal, and has the reference of (70.70), the same as that given to the point *o* of the magistral of the scarp of the cut. The parapet in rear of this magistral, *o t*, is not exposed to direct fire, and is made with the least thickness allowed. In this example it is taken to be twelve feet thick, although as a rule, a thickness of eighteen feet should be the least for any parapet in a permanent fortification. The interior crest is held in the plane containing the crest *d e*, and a point three feet above the interior crest of the ravelin at its salient.

The terre-plein is made, as in the other cases, parallel to the plane of the interior crest and eight feet below it. It is con-

nected with the bottom of the redoubt ditch by the gorge wall $g\ o'$, and terminated on the side toward the main ditch by the wall joining the extremity of the magistral of the ravelin face and the end of the ravelin redoubt.

Access to this terre-plein is by a postern and winding stairs leading from the main ditch.

48. Remarks upon the Cut.—The position and form of the cut are such as to allow the ditch of the redoubt of the re-entering place-of-arms to be swept by a fire from the ravelin redoubt, at the same time it isolates the dangerous part of the ravelin face from the portion in front of the cut.

The slope given to the bottom of the cut masks the masonry of the scarp of the ravelin face from the fire of breaching batteries that may be established upon the glacis of the re-entering place-of-arms. The height of the bottom of the cut above the bottoms of both ditches, makes it practically safe from assault. Even if reached, the parapet behind it is safe from assault.

49. Bastion Covered Way and Re-entering Place-of-arms.—The crest of the covered way in front of the salient of the bastion is parallel to the counterscarp and 11.0 yards from it.

The crest of the re-entering place-of-arms is parallel to the magistral of its redoubt, and 20.0 yards from it.

Lines drawn parallel to these lines and at these distances from them, will be the projections of the crests of the covered way in front of the bastion and of the place-of-arms.

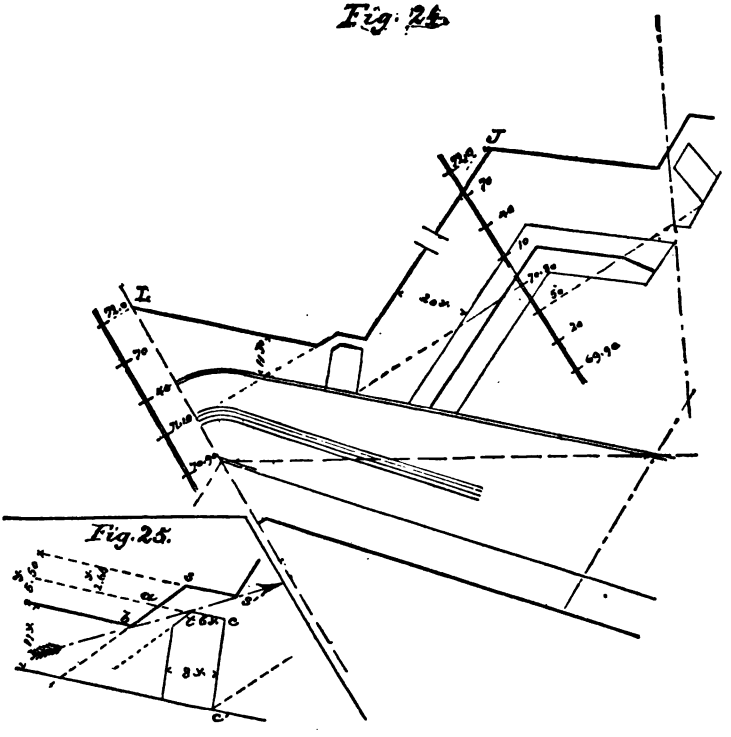
The covered way at its salient, L (Fig. 24), is made to command the covered way of the salient of the ravelin by one foot and a half, which gives for that point a reference of (72.0), or a height of twelve feet above the plane of site.

The interior crest of the covered way of the bastion is held in a plane whose scale of slope is parallel to the bastion capital, and whose inclination is such as to have the plane

prolonged pass three feet above the salients of the salient places-of-arms of the adjacent ravelins.

The crest of the salient, J, of the re-entering place-of-arms is placed at the same height as that of the salient of the bastion covered way, or has a reference of (72.0). Its crest is held in a plane fulfilling similar conditions to that of the covered way.

Fig. 24.



The terre-plein of the re-entering place-of-arms is connected with the bottom of the ditch of its redoubt by an easy slope which can be used by infantry. It is also connected by ramps of sufficient width for artillery.

The width of 11.0 yards is given to the bastion covered way to allow room for a banquette tread, banquette slope, and a road. The banquette tread is made 2.0 yards wide, to

leave room for palisades that are used when the work is put in a state of defence in time of siege. It is probable that palisades will not be used in the future, as recent sieges have demonstrated their inefficiency. The narrowing of the banquette will bring the crest of the glacis nearer to the counterscarp, and will afford greater protection to the masonry from an enemy's fire; and for this reason the palisading will probably be abandoned.

50. Traverse on the Bastion Covered Way.—If the interior crest of the bastion covered way be produced until it intersected the crest of the re-entering place-of-arms, there would be an open space between this point and the counterscarp of the main ditch, that could be seen from the glacis of the bastion covered way on the opposite side of the bastion salient. This open space would allow a fire from this glacis into the interior of the re-entering place-of-arms. A traverse is placed in front of this opening to intercept this fire (Fig. 24). This traverse is placed with one end upon the counterscarp of the bastion, and the other 2.84 yards beyond the crest of the covered way produced (Fig. 25). It is provided with a parapet, and has a passage-way around the outer end to allow persons to pass around the traverse. The ends of the traverse are revetted.

The thickness of the traverse is that of the general parapet exposed to artillery fire.

The projections of the interior and exterior crests of the traverse are drawn as follows:

A line, *a c* (Fig. 25), is drawn parallel to the crest of the bastion covered way and 2.84 yards from it; the point of intersection of this line with the interior crest of the re-entering place-of-arms produced is the projection of the extremity of the interior crest of the traverse; through this point, *c*, draw a line perpendicular to the magistral of the counterscarp of the main ditch; this line, *c c'*, is the projection of the interior

crest of the traverse. A line drawn parallel to the interior crest and 8.0 yards from it will be the indefinite projection of the exterior crest, as this is the thickness of the parapet used. The exterior crest is limited by a passage-way made around the end of the traverse.

The passage-way is an open one with revetted sides, and is made as follows:

A line, *s s'*, is drawn parallel to the crest of the bastion covered way and 2.66 yards from the end, *c*, of the traverse; the point, *s'*, where this line *s s'* intersects the crest of the re-entering place-of-arms, will be the intersection of the passage-way with the interior crest of the re-entering place-of-arms.

The point where the passage-way intersects the crest of the bastion covered way is determined by drawing a line through *s'* and an assumed point, as *t*, upon the traverse and finding its intersection, *b*, with the crest. In this case the point, *t*, is taken 6.0 yards from *c*, and the point *b* is where the passage-way intersects the crest of the bastion covered way.

The side *s s'* of the passage-way is parallel to the end of the traverse; the side *b s* passes through *b* and 2.66 yards from *t*, the assumed point on the traverse.

The exterior crest of the traverse is limited by the line drawn through *t* parallel to the side *b s* of the passage-way.

The distance of 2.66 yards is taken to allow a width of 2.0 yards for the passage-way at the bottom. The end of the traverse is held up by a vertical wall that rises to a level with the surface of the traverse. The earth of the glacis forming the outer side of the passage is held up by a vertical wall that rises to within eighteen inches of the crest, and by a slope of earth for this remaining distance. A berme of six inches is left on top of this wall, which, added to the base of the slope of earth, gives two feet, or 0.66 of a yard; this, added to the width of passage-way, 2.0 yards, gives the distance 2.66 yards.

It is seen that the construction given for the passage-way makes it secure from the enemy's fire, and allows it to be seen from works in its rear.

The interior crest of the traverse is held in the plane of the crest of the re-entering place-of-arms. This height, with its thickness of 24.0 feet, protects the terre-plein of the re-entering place-of-arms from the fire to which it would otherwise be exposed.

51. Ravelin Covered Way.—The covered way enveloping the ravelin is a crémaillère line. The long branches are given a direction very nearly parallel to the ravelin ditch, and the short ones are made perpendicular to the ravelin capital (Fig. 26). The ravelin covered way, from its position, is almost always exposed to enfilade fire. It is therefore usually protected from such fire by means of traverses.

The traverses are made with parapets, and have open passage-ways leading around the ends next to the glacis.

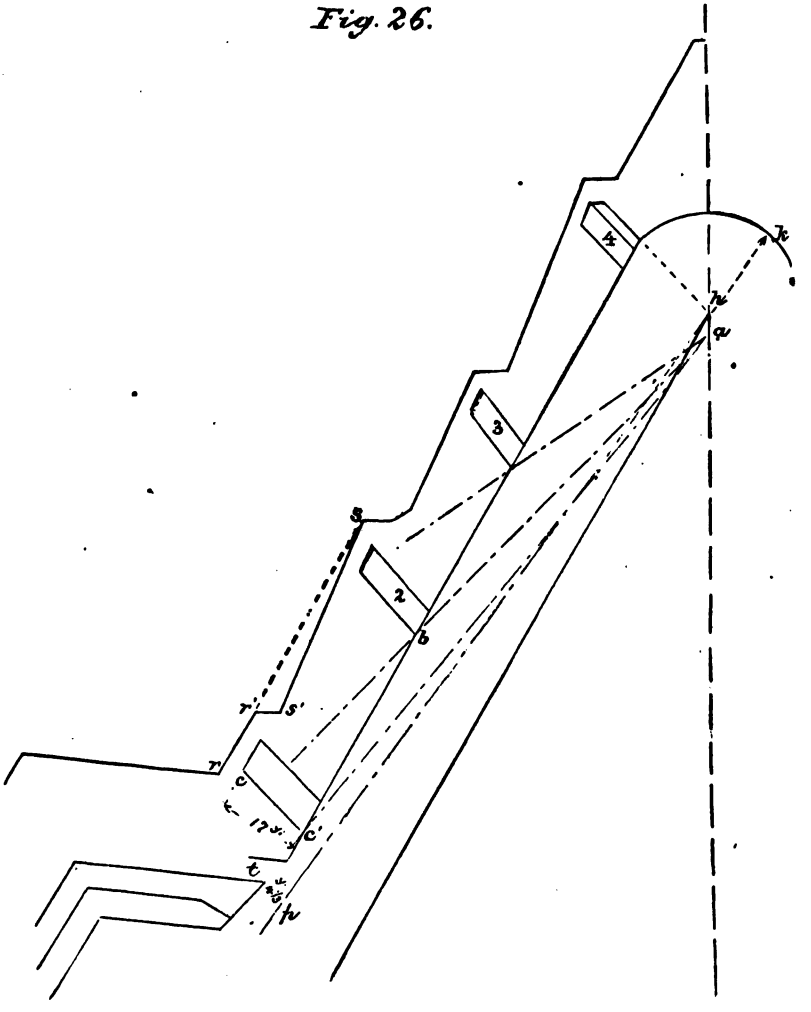
The main object of the short branches of the crémaillère line is to give shelter to the passage-ways, although they are provided with banquettes by means of which a fire can be had from the short branches, in the direction of the ravelin capital, upon the glacis. In the front now being considered there are four traverses used on each side of the ravelin (Fig. 26). For convenience of description the traverses are numbered from 1 to 4, No. 1 being the traverse used to screen the interior of the re-entering place-of-arms from fire coming from the glacis around the ravelin salient.

The construction of traverse No. 1 is as follows: The extremity of the interior crest next to the glacis is on the crest of the place-of-arms produced and 17.0 yards from the ravelin counterscarp; find this point, c, and draw through it a line, $c\ c'$, so that the line shall be perpendicular to a line joining c' with a; this line, $c\ c'$, is the projection of the interior crest of the traverse.

The projection of the exterior crest is parallel to that of the interior crest and 8.0 yards from it.

The end of the traverse next to the glacis is parallel to the counterscarp of the ravelin, and sustained by a wall.

Fig. 26.



The interior crest of the traverse is in the plane of the crest of the re-entering place-of-arms.

The passage-way between the end of the traverse and the glacis is made 2.0 yards wide at bottom. A line, $r\ r'$, drawn parallel to the end of the traverse and 2.66 yards from it, gives the position of the passage-way. The crest of the short branch, $r'\ s'$, of the crémaillère line, next to this traverse, is 5.66 yards from the extremity of the exterior crest next to the glacis. A line drawn perpendicular to the ravelin capital and 5.66 yards from the extremity of the exterior crest of the traverse is the projection, $r'\ s'$, of this short branch. The intersection, r', of this line with the side $r\ r'$ of the passage-way, 2.66 yards from the end of the traverse, is where the short branch begins. It is made 6.66 yards long.

The distance 2.66 yards, used in this construction, is explained in the previous article. The distance 5.66 yards is obtained as follows:

A banquette is used with the short branch, and is made 2.0 yards wide. Its tread is 4.5 feet below the interior crest, and 3.5 feet above the bottom of the passage. The interior slope is $\frac{3}{1}$. The banquette slope is $\frac{1}{1}$. The horizontal distance, from the wall of the passage-way at the extremity of the exterior crest of the traverse to the interior crest, $r'\ s'$, of the short branch, is composed of the width of passage-way, 2.0 yards; the base of banquette slope, $3'.50 = 1.16$ yards; the width of banquette tread, 2.0 yards; and the base of interior slope, $1'.5 = 0.5$ of a yard. Hence the horizontal distance is $(2.0 + 1.16 + 2.0 + 0.5) = 5.66$ yards.

The banquette slope is made $\frac{1}{1}$ to bring the crest of the short branch nearer to the traverse.

The extremity, s', of the crest of the short branch is one point of the projection of the crest of the long branch next to it. A second point of the long branch will be more conveniently obtained after having first located the position of traverse No. 2.

The projection of traverse No. 2 is determined as follows:

An arc is described with the extremity s' of the short branch as a centre, and a radius of 6.66 yards; a right line, $a\ b$, is drawn through a on the ravelin (Fig. 27) tangent to this arc; the point at which this tangent line cuts the counterscarp of the ravelin is the projection of the extremity of the interior crest of the traverse; through this point, b, of the crest draw a line perpendicular to $a\ b$, and it will be the indefinite projection of the interior crest; a line drawn parallel to the interior crest, and at a distance of 6.0 yards from it, will give the indefinite projection of the exterior crest; the end of the traverse is made parallel to the long branch of the crémaillère line, and 2.66 yards from it. The extremity, s, of the long branch is required to be upon the line $r\ r'$ (Fig. 26), produced. The extremity of the exterior crest of the traverse is required to be 2.66 yards from the long branch, $s\ s'$, and 5.66 yards from the short branch drawn from s. A point must therefore be found upon the exterior crest that shall be 5.66 yards from a perpendicular to the ravelin capital drawn through s and 2.66 yards from the long branch, $s\ s'$.

This construction is made by assuming a point on the projection of the exterior crest, and describing two arcs with radii of 2.66 and 5.66 yards respectively; a tangent line is drawn to the arc of 5.66 yards radius and perpendicular to the ravelin capital, and a line through s' is drawn tangent to the arc of 2.66 yards radius; if these tangent lines intersect on the line $r\ r'$ produced, the point of intersection, s, is the other extremity of the long branch. If they do not intersect on the line, another point is assumed and the construction continued until this condition is satisfied.

The projection of traverse No. 3 is determined by taking a point, o (Fig. 27), on the crest of the short branch next to No. 2, at a distance of 4.33 yards from the extremity, s, as a centre, and describing an arc with a radius of 4.50 yards; a line is then drawn through a tangent to this arc; the point, b', where

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this line intersects the counterscarp, is the projection of the extremity of the interior crest of the traverse. The rest of the projection is obtained exactly as in the case of No. 2, excepting that the long branch is made to terminate 2.0 yards nearer to the counterscarp than was required in the last case.

The crest of the short branch near No. 2 is not made perpendicular to the ravelin capital for the entire distance of 6.66 yards, but changes direction at a point taken 4.33 yards from its extremity, and for the rest of its length is made parallel to the line $a\ b'$ drawn through a tangent to the arc, the centre of which was this point at 4.33 yards from its end.

The projection of traverse No. 4 is obtained by drawing a right line through a point, p (Fig. 26), in the ravelin ditch, 4.33 yards from the extremity, t, of the magistral of the redoubt of the re-entering place-of-arms and the salient, h, of the ravelin magistral; then producing this line until it intersects the ravelin counterscarp; the point of intersection, k, is a point of the projection of the foot of the exterior slope of the traverse.

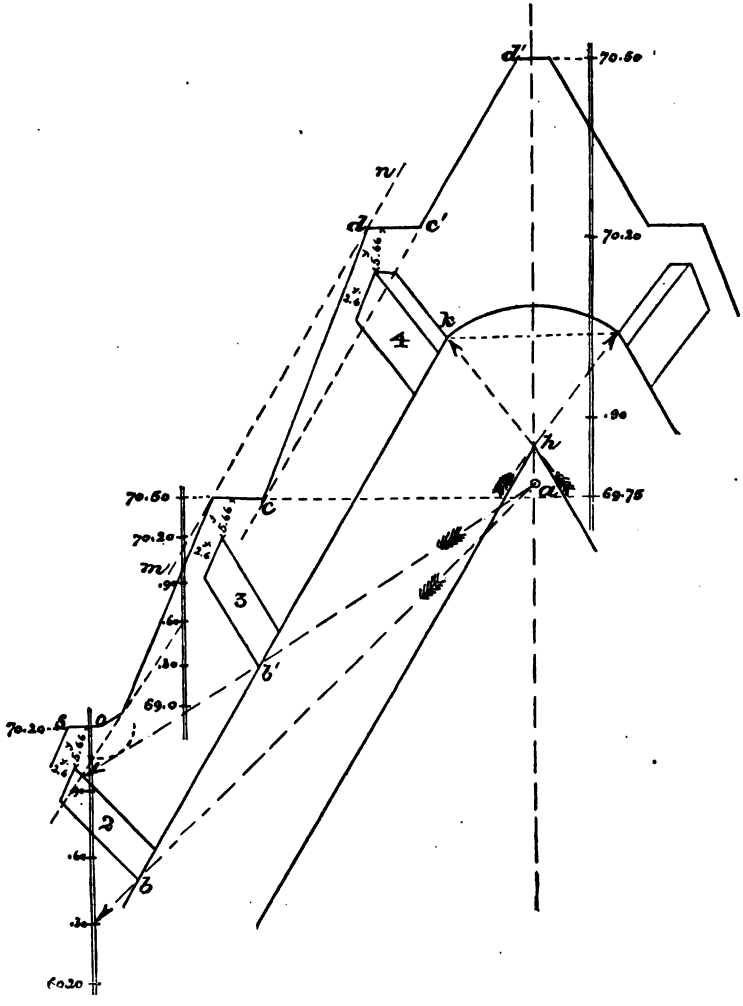
The interior crest of the traverse is parallel to the line $h\ k$ (Fig. 27), and is eight feet above the terre-plein of the covered way. The horizontal distance of the interior crest from the foot of the exterior slope is $28' = 9.33$ yards; a line drawn parallel to and 9.33 yards from $h\ k$ is the projection of the interior crest. A line drawn parallel to and 8.0 yards from the interior crest is the projection of the exterior crest. The end of the traverse is parallel to the long branch of the crémaillère line next to it. This branch is determined by the same method as that for the preceding one, the extremity being on the same line, $m\ n$ (Fig. 27), and 2.66 yards distant from the end of the traverse.

The crest of the salient place-of-arms is drawn through the

end of the short branch in front of No. 4, parallel to the ravelin counterscarp. A pan-coupé is made in its salient.

It is only necessary to fix the references, to have the crest of the ravelin covered way and its traverses completely given.

Fig. 27.



The salient of the salient place-of-arms has already been fixed at 10.50 feet above the plane of site, or has a reference

of (70.50). The crest of the salient place-of-arms, the interior crest of traverse No. 4, and the crest of the long branch between traverses Nos. 3 and 4 are held in a plane whose scale of slope is parallel to the ravelin capital, and whose inclination is such that there shall be a fall of 0.75 of a foot from the salient of the salient place-of-arms to the extremity of the long branch. This gives the extremity, *c* (Fig. 27), of the branch a reference of (69.75). The references (70.50) and (69.75) and direction of scale of slope being fixed, the scale is constructed and the plane is fully determined.

The crest of the short branch next to traverse No. 3 is given the same reference as that of the salient of the salient place-of-arms (70.50). This crest, the interior crest of traverse No. 3, and the crest of the long branch adjacent are held in a plane that passes 3.0 feet above the salient of the salient place-of-arms, and has its scale of slope parallel to the ravelin capital.

The crest of the long branch in rear of traverse No. 2, the interior crest of No. 2, and the portion, *s o*, of the short branch perpendicular to the ravelin capital are held in a plane that passes 3.0 feet above the salient, as in last case, and whose scale of slope is also parallel to the ravelin capital. The portion *o s* is given a reference of (70.20), which fixes the position of the plane.

The portion of the crest from *o* to the long branch is in the plane of the crest of the latter. Instead of using a banquette slope for this part, steps are employed by which the men mount the banquette.

52. Remarks upon the Covered Way.—The general arrangement of the crest is to place it far enough from the ditch which it envelops to leave room for a parapet and a roadway in its rear twenty feet wide. This width of roadway will allow troops to be assembled at any part of the covered way in considerable numbers. The besiegers, when near the

work, will not only be under a close fire of small-arms, but will also be exposed to sudden attacks from the men assembled in the covered way. The fear of these attacks will force the besiegers to keep larger numbers in readiness to repulse sorties and to protect the sappers and the working details in the trenches. These forces are necessarily compelled to occupy cramped positions, are more or less exposed to the fire of the work, and are subjected to much fatigue and suffering. The labor of trench duty is thereby increased, and the difficulties of taking the work augmented.

The covered way affords facilities for posting sentries on the further side of the ditch to guard against surprise, and for sending out patrols to examine the ground exterior to the work.

As an outwork it is almost indispensable, and in the words of Vauban, the covered way "costs less to the defence, and more to the assault, than any other work."

Traverses, while they cramp the covered way and interfere with its use as a roadway, are necessary to defilade the terre-plein from the enemy's fire.

The traverses used to protect the interior of the places-of-arms are given the full thickness of the main parapet; in this case, 24.0 feet. Those on the ravelin covered way having for their object to defilade the terre-pleins in rear of them are made only 18.0 feet thick.

The interior crests of traverses Nos. 1, 2, and 3 are arranged to allow a fire to be delivered from all of them upon the salient place-of-arms, and the traverses are placed so that each traverse and the ravelin, taken together, mask the passage-way around the traverse in rear of it. These passage-ways are not expected to be used by artillery, and are therefore made only two yards wide. No attempt is made to mask the passage-way at its outlet around traverse No. 3.

Traverse No. 4 is arranged so as to allow the foot of its exterior slope to be swept by the fire of the bastion.

The crests of the branches of the covered way and the interior crests of the traverses are held in planes so inclined as to defilade the terre-pleins from the enemy's fire from the glacis of the salient place-of-arms. This arrangement of the crests has the effect of placing the terre-plein of the covered way on different levels. These levels are connected by small ramps at the outlets of the passage-ways.

The traverses on the ravelin covered way must not be placed too far apart. The distance apart should not be so far as to allow a shot grazing the interior crest of a traverse to reach the terre-plein in its rear. Knowing the inclination of the trajectory of the shot as it grazes the crest, and the height of the crest above the terre-plein, the distance apart of the traverses may be determined. For example: Suppose an inclination of $\frac{1}{10}$ to be assumed for the trajectory, and a height of 8.0 feet for the crest above the terre-plein. Dividing 8.0 feet by the slope of $\frac{1}{10}$, there results a distance of 80'.0 = 26.6 yards for the superior limit of the distances apart of the traverses. Any distance greater than this limit would allow a shot grazing the crest to reach the terre-plein; any distance less than this would cause the shot to strike the second traverse.

The width of covered way, when wide, adds to the difficulty of screening the masonry of the scarp wall of a work from the **indirect** fire of an enemy. The crest of the covered way hides the masonry from direct fire, but by its distance from the scarp does not prevent the masonry from being reached by **curved** fire. The introduction of rifled cannon has given great value to this latter fire, and has made it necessary to screen the scarp walls from it.

53. Glacis.—The object of the parapet of the covered way is to shelter the troops occupying the covered way. Its upper surface, or glacis, is arranged so as to leave no dead spaces in which an enemy could be hidden from the view of the defence.

In arranging the glacis, care should be taken to have it swept by the artillery fire of the work in its rear and by the fire of small-arms from the bastion.

It is seen from the angular directions given to the crest of the covered way and the variations in its command, that the surface of the glacis will be composed of a number of planes containing the crest of the covered way and having different inclinations. The conditions imposed upon these planes are that they shall be swept by the fires, as just stated, and that their slopes shall be neither too steep nor too gentle.

A steep slope has the advantage of requiring less embankment and of exposing to a greater degree the enemy's trenches upon the glacis to a reverse view from collateral works. The problem of thoroughly sweeping the planes by the fire of the works near them becomes, however, more difficult to solve.

A gentle slope is more easily swept, and gives less trouble to remove the dead spaces, but it is more expensive to construct from the greater amount of earth-work required.

The glacis planes are generally made so as to keep their inclinations between $\frac{1}{16}$ and $\frac{1}{40}$, although these limits are occasionally passed, under peculiar circumstances.

In the example of the half front taken for description, it will be seen (Fig. 34) that the surface of the glacis is composed of ten planes, counting from the capital of the ravelin to the capital of the bastion. No invariable rule is followed for the construction of these planes. The method used in the construction of this trace is as follows:

Glacis plane No. 1, or the glacis slope bounded by the crest of the salient place-of-arms and the ravelin capital, is determined by passing a plane through this crest, c' d' (Fig. 27), and a point on the salient of the ravelin, three feet below the pan-coupé.

The next plane, or No. 2, numbering in order from the ravelin capital to that of the bastion, is determined by passing

a plane through the outer extremity, *d*, of the short branch, *c′ d*, through a point on the interior crest of the ravelin, 20 yards from its pan-coupé lowered one foot and a half, and the middle point of the interior crest of the bastion face. These three points fix the plane containing the short branch of the covered way next to the salient place-of-arms.

Plane No. 3 is determined by passing a plane through the long branch, *c d*, of the covered way next to traverse No. 4, and through the point of the interior crest of the ravelin, 20 yards from the salient, lowered *three* feet.

Plane No. 4 is determined by passing a plane through the point of the interior crest of the ravelin 20 yards from its salient, lowered three feet, through the outer extremity of the short branch next to traverse No. 3, and through the middle point of the interior crest of the bastion face.

Plane No. 5 is determined by passing a plane through the same point on the ravelin as that used for No. 4, and through the crest of the long branch of the covered way next to traverse No. 3.

It will be better for description to pass over at present planes No. 6 and No. 7, and determine first the positions of Nos. 10, 9, and 8.

Glacis plane No. 10, or the plane bounded by the bastion capital and covered way, is determined by passing a plane through the crest of the bastion covered way and a point of the interior crest of the salient of the ravelin of the adjacent front.

Plane No. 9, next to No. 10, is determined by passing a plane through the crest of the side of the re-entering place-of-arms next to the bastion capital, and through a point one foot and a half below the extremity of the interior crest of the redoubt of the re-entering place-of-arms next to the bastion.

Plane No. 8 is determined by passing a plane through the

crest of the re-entering place-of-arms on the side next to the ravelin, and through the middle point of the interior crest of bastion face.

Plane No. 7 is determined by finding the point where the intersection of Planes 8 and 9 pierces the plane of site. A plane passed through this point and the long branch of the covered way next to traverse No. 2 gives the position of glacis plane No. 7.

Glacis plane No. 6 is determined by passing a plane through this same point of intersection, through the outer extremity of the short branch next to traverse No. 2, and through the middle point of the interior crest of the bastion face.

This arrangement of the slopes allows every part of the glacis to be swept by the artillery fire of part of the ravelin and by the fire of small-arms from at least half of the bastion face.

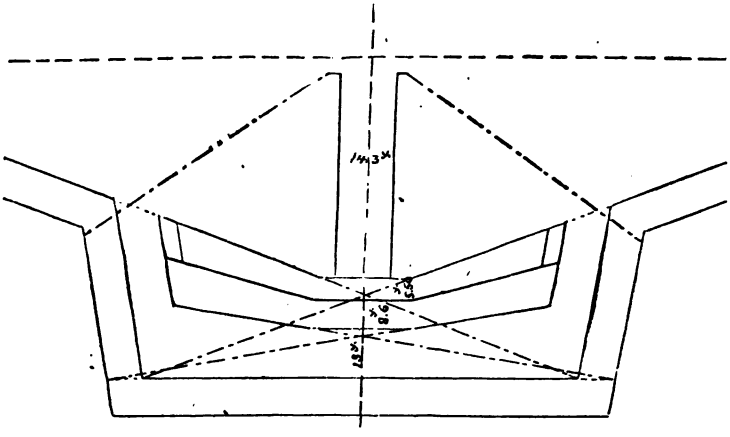
54. Tenaille.—It has been stated that it is necessary to arrange the parts of the work so as to hide the scarp walls from the enemy's view, and that the introduction of rifled cannon will even require these walls to be protected from **indirect** fire. The scarp of the curtain is peculiarly exposed to this fire, and on fronts exposed to attack by siege operations, a mask is placed in the main ditch to protect the masonry of the curtain. This mask is called the **tenaille.** The tenaille is composed of a curtain and two wings; the magistral of its curtain being parallel to that of the curtain of the main work, and the magistrals of the wings being projected in the lines of defence. This work is entirely separated from the main work; its ends being placed 11.0 yards from the scarps of the flanks, and its gorge 13.0 yards from the scarp of the curtain of the main work (Figs. 28 and 30). It is made with a parapet arranged for infantry and only 12.0 feet thick. The interior crest is made hori-

zontal. The parapet terminates at the ends of the wings in traverses 12.0 feet thick, whose upper surfaces are on a level with its interior crest.

The terre-plein is made 20.0 feet wide at the curtain, and wider at the wings. It is placed eight feet below and parallel to a plane containing the interior crest and a point on the gorge of the ravelin redoubt, three feet above the interior crest of the redoubt at its extremity.

The interior crest of the tenaille must not be so high as to interfere with the fire of the flanks reaching the bottom

Fig. 28.



of the ditch along the bastion faces. It is therefore taken 4.50 feet lower than the magistral of the curtain of the main work. As this latter line has a reference of (68.0), or is 13.0 feet below the interior crest of the main work, this condition of 4.50 feet lower fixes the reference of the interior crest of the tenaille at (63.50), or 27.0 feet above the bottom of the main ditch at the middle of the curtain. The tenaille in this example is revetted, having a scarp wall, a gorge wall, and profile walls holding up the ends of the wings.

Before fixing the exact position of the tenaille curtain magistral, it is necessary to know its horizontal distance from

the interior crest of the tenaille. This is easily obtained after the height of the magistral is fixed.

In this front, a postern is carried under the middle of the main curtain, having its outer end exposed to the fire of the flanks but protected from the enemy's fire by the tenaille. This end of the postern connects with a level passage-way in the bottom of the ditch, leading under the tenaille by a postern, and across the main ditch.

From the tenaille to the opposite side of the ditch it is an open passage-way sheltered on the sides by parapets of earth. These parapets are made 9.0 feet high, and are arranged with banquette treads. The crests of the parapets are connected with the bottom of the ditch by gentle slopes of earth. The whole arrangement is called the **double caponier.**

The crest of the double caponier being 9.0 feet above the bottom of the ditch, has a reference of (45.50), the reference of the passage-way being (36.50). Following the general rule of making the scarp wall at least 13.0 feet high, it is seen that the top of this wall should be 13.0 feet above the crest of the double caponier, or must have a reference of (58.50).

Giving the magistral of the tenaille curtain this reference of (58.50), the line can easily be drawn. The construction is as follows:

Parallel to and 13.0 yards from the magistral of the curtain of the main work, a line is drawn; this line is the magistral of the gorge wall; parallel to this line and 20.0 feet, or 8.66 yards, from it, a second line is drawn; this gives the projection of the interior crest of the tenaille; parallel to this line and 5.50 yards (the horizontal distance being equal to $12'.0 + 3'.0 + 1'.5 = 16'.5 = 5.50$ yards) from it, a line is drawn; this line is the magistral of the tenaille curtain. It is limited by the lines of defence.

The magistral of the wing is a broken line, and has the following position: The scarp wall at the end of the wing is

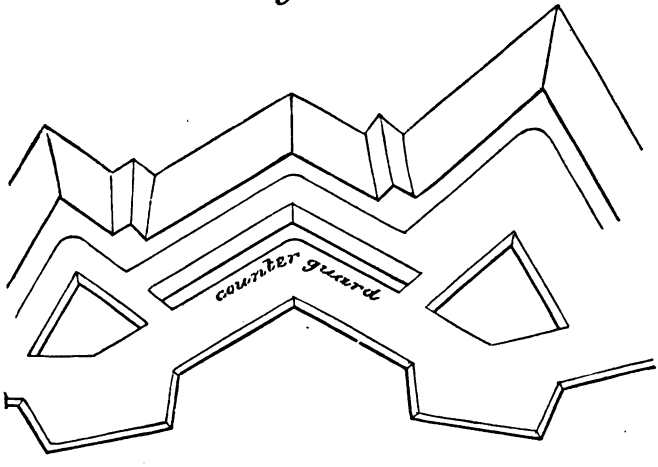
carried up to the top of the traverse. The magistral is horizontal for the width of the traverse, 12.0 feet; it then has a slope of $\frac{1}{4}$ until it is within 13.0 feet of the bottom of the ditch; from this latter point it has a slope upward to the point where it joins the curtain. It is only necessary to find the lowest point and fix the reference to complete the magistral of the wing. This point is determined as follows: Parallel to and 11.0 yards from the magistral of the flank, draw a line; this line is the magistral of the profile wall holding up the end of the tenaille (Fig. 30). Parallel to this line and 4.0 yards from it, a line is drawn; this is the projection of the edge of the traverse, and its intersection with the projection of the magistral of the wing is the point where the magistral begins to descend with a slope of $\frac{1}{4}$. The ditch at the middle of the curtain has a reference of (36.50) and slopes from this part to the shoulder angle, 3.0 feet. It therefore has a reference of 33.50 at the end of the tenaille. The top of the traverse has the same reference as the interior crest, or (63.50), and is therefore 30.0 feet above the bottom of the ditch. The base of the slope of the magistral, from the top of the traverse to the lowest point, will be equal to the difference in height of these two points, or 17.0 feet, since the lowest point is taken 13.0 feet above the bottom of the ditch. A line drawn parallel to the traverse and $17'.0 = 5.66$ yards from it will intersect the magistral at its lowest point, or the point whose reference is (46.50). The references being known, the magistral of the wing is fully determined.

The interior crest is parallel to the curtain and 5.50 yards from it; its horizontal distance from the lowest point of the magistral is $12'.0 + 15'.0 + 1'.5 = 28'.50 = 9.50$ yards; a line drawn so as to be 5.50 yards from the point where the magistral of the wing intersects that of the curtain, and 9.50 yards from the point whose reference is (46.50), will be the interior crest of the wing of the tenaille.

The gorge wall rises to the level of the terre-plein, and for the curtain is parallel to the interior crest. It is not parallel for the wing but flares out, making the terre-plein wider. The magistral of this wall is obtained by taking the point where the magistral of the curtain of the main work produced intersects the interior crest of the flank (Fig. 28), and drawing through it a line which shall be 20′.0 = 8.66 yards from the point of intersection of the interior crest of the wing and curtain of the tenaille farthest from it. This line produced gives the direction of the gorge wall for the wing.

55. Remarks upon the Tenaille.—The tenaille is simply a mask for the masonry of the curtain and flanks. It is,

Fig. 29.



however, arranged for defence by giving it a parapet. Mortars are sometimes placed upon its terre-plein.

In this example the tenaille is provided with a scarp wall, and the usual conditions of an outwork imposed upon it. It is not uncommon, however, to dispense with masonry walls in its construction, excepting for the ends.

The traverses, at the ends, are to add to the protection given to the masonry of the flanks. It is seen that if trav-

erses were not used, and the exterior slope of the parapet extended to the extremity of the wing, a large part of the scarp of the flank would be exposed to the enemy's fire.

The masonry of the curtain scarp is not entirely protected, since the interior crest of the tenaille is lower than the top of the curtain scarp wall. A higher position would have afforded greater protection to the masonry, but would have interfered with the efficient flanking of the main ditch.

56. Counter-guard.—An outwork which has for its principal object the protection of the scarp wall of the faces of a bastion is termed a **counter-guard.** The scarps of the faces of a bastion, when the ditch is a wide one, are liable to be battered down by indirect fire. In this case the work used to protect them is usually a redan in form that envelops the exposed faces (Fig. 29).

The counter-guard is made with a parapet from which a fire can be had upon the ground in front of it. It may be made with a scarp wall, but it is not always so made, as it is considered better to give the scarp a gentle slope, forming an **inner glacis** that can be thoroughly swept by the fire of the main work.

When not provided with a parapet, the counter-guard is usually designated a **face-cover**—a term also applied to any work which screens a face of a work.

When several counter-guards are connected together they form what is known as an **envelope.**

57. Double Caponier.—The arrangement made to shelter the open passage-way across the ditch is called the **double caponier** (Art. 54).

The passage-way is at the bottom of the ditch, is level, and made 10.0 feet wide. It is sheltered by parapets on each side, parallel to the length of the passage-way. Its reference is (36.50).

Each parapet is provided with a banquette tread, 2.0 yards

wide. The superior slopes of the parapets are prolonged to the bottom of the ditch, forming glacis surfaces so inclined as to allow them to be thoroughly swept by embrasure fire of the flanks. The crests are terminated at one end by the tenaille, and at the other by a profile wall ten feet from the exterior side.

The method of constructing the trace is as follows:

The horizontal distance between the two crests is composed of the width of the passage-way, the width of the banquette treads, and the bases of the interior and banquette slopes. This distance is equal to 43.0 feet, or 14.33 yards.

Two lines drawn at equal distances on each side of the perpendicular of the front, parallel to it, and 14.33 yards apart, will give the projections of the crests. They are terminated by the tenaille, and by a line parallel to the exterior side and 10.0 feet from it.

The superior slope of either parapet is determined by passing a plane through the crest of the parapet and a point taken *three* feet below the interior crest of the main work at the shoulder angle of the bastion behind the parapet.

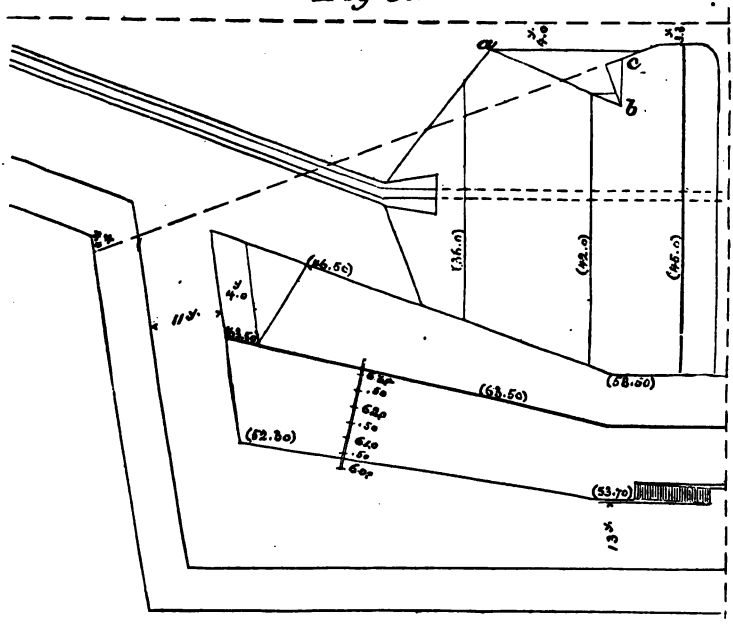
The profile wall which holds up the outer end of the parapet is made parallel to the exterior side for a distance of 2.0 yards. It is then changed in direction, being directed upon a point of the interior crest of the flank, 4.0 yards from the shoulder angle (Fig. 30).

To remove the dead space that would exist at the outer end if the superior slope of the parapet remained in the plane passing through the point near the shoulder angle, a part of this slope is cut away by a plane passed through the interior crest of the curtain of the main work and intersecting the bottom of the ditch in a line 4.0 yards from the exterior side. This second plane intersects the superior slope in a right line, *a b* (Fig. 30), which is terminated at *b*, 24 feet from the crest, or the thickness of the parapet. The line *b c* forms the exterior crest of this outer end of the parapet, and the exterior

slope through *b c* is made $\frac{1}{4}$. The point in which the line of intersection of the plane of the exterior slope of this part of the parapet and the plane through the interior crest of the main curtain, intersects the line drawn to the point 4.0 yards from the shoulder angle, determines the end of the profile wall.

58. Remarks upon the Double Caponier.—The object of the double caponier is to shelter the open passage-way leading from the tenaille across the bottom of the ditch, from an enemy's fire from the glacis of the bastion salient. It is made a defensive work by giving it a parapet, although it is not likely to be of much use for such purpose.

Fig. 30.



Great care is taken to arrange its slopes so as to remove the dead spaces which it otherwise would make in the ditch. It was with this object in view that, after leaving a sufficient thickness of parapet, a part of the slope was cut away, or made into a **glacis coupé.**

The parapet was terminated on a line ten feet from the exterior side, because the passage-way at that end was sheltered from the enemy's fire by the part of the counterscarp called the **face-cover.**

59. Counterscarp of the Bastion.—The construction of the magistral of the counterscarp of the bastion was made (Art. 32) so as to have the end rest on a line ten feet within the exterior side, or on a line with the outer end of the double caponier. This extremity is made high enough to intercept a line of fire coming from a point *three* feet above the crest of the bastion covered way, and passing 7.50 feet at least above the bottom of the ditch at the end of the caponier. When this is done, the passage-way as it leaves the caponier is sheltered from the fire of the bastion covered way. If the top of the counterscarp wall at the extremity be given a reference of (57.0), it will be seen that the line of fire will pass at least 7.50 feet above the bottom of the ditch at the outer end of the caponier. Giving it this reference fixes one point of the magistral of the counterscarp (Fig. 31).

The top of the bastion counterscarp wall should be at least eight feet below the plane of the crest of the bastion covered way. Taking it at eight feet below, fixes the reference of the top of the wall at the salient, or makes it (62.40). The references at the extremity and at the salient being given the magistral of the counterscarp is fixed.

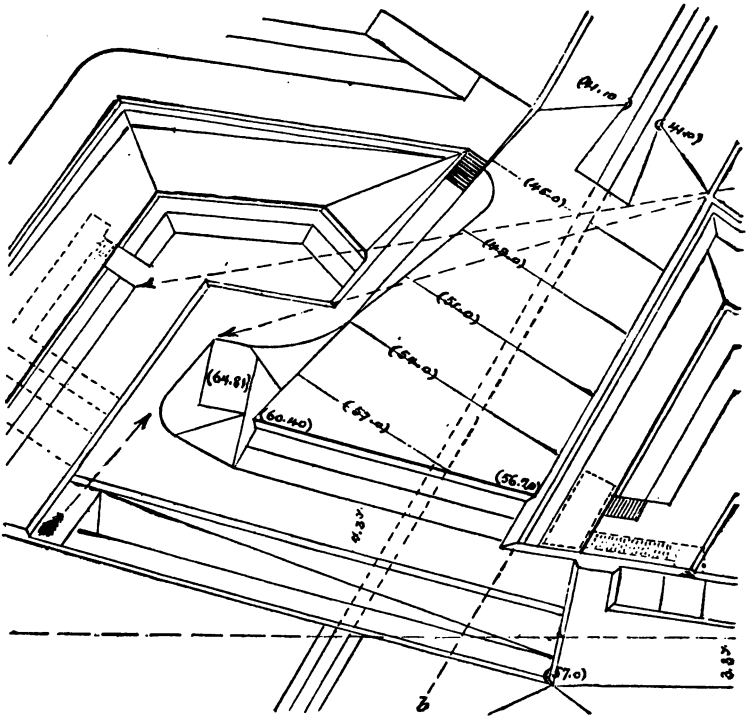
The counterscarp wall should be high enough to make it an obstacle of value for the defence. In this example it is therefore made 23.0 feet high at the salient, and 22.5 feet at the extremity. These heights place the bottom of the ditch along the counterscarp about six feet above the bottom along the foot of the scarp.

60. Face-cover.—The portion of the counterscarp wall which crosses the prolongation of the ravelin ditch partially masks the masonry of the scarp of the bastion face from an

enemy's fire from batteries on the glacis of the ravelin salient. The masonry wall of the counterscarp on the side next to the ravelin is protected against artillery fire by earth, and this portion of the counterscarp is called the **face-cover.**

The embankment resting against this wall is made in the example 9.0 feet thick at the top, and is sloped toward the ravelin ditch (Fig. 31). A passage-way across the ravelin ditch runs along the foot of the slope of the face-cover.

Fig. 31.



61. Single Caponier in the Ravelin Ditch.—The open passage-way across the ravelin ditch is protected from an enemy's fire from the glacis of the salient of the ravelin by a parapet of earth which is known as the **single caponier.**

The crest of the caponier is made parallel to the passage-way and the superior slope is prolonged until it intersects the bottom of the ravelin ditch. Care is taken to arrange the slope so as to remove any dead space in the ravelin ditch made by the caponier, or that would exist if the caponier were not used. The object of the single caponier is to remove the dead space in the lower end of the ravelin ditch as well as to protect the open passage-way leading across it.

The construction used in the example (Fig. 31) is as follows:

Take the point, *b*, where the ravelin magistral produced intersects the interior crest of the bastion face, a point in the ravelin ditch below the bottom of the ditch of the redoubt of the re-entering place-of-arms, and a point of the same ditch opposite, below the cut in the ravelin face. Through these three points a plane is passed in which the crest of the caponier is to be held. The interior crest is drawn in projection parallel to the magistral of the bastion counterscarp, and far enough from the face-cover to allow room for the open passage-way, and the interior part of the parapet.

The passage-way is 4.33 yards wide, and has the side next to the parapet parallel to the interior crest of the caponier. The bottom of the passage-way is placed eight feet below the interior crest. The parapet has a banquette tread of 2.0 yards wide, which is connected with the bottom of the passage-way by a slope of $\frac{1}{4}$.

The extremity of the bastion counterscarp was placed 11.0 yards distant from the end of the ravelin face, this distance being sufficient to allow room for the slope of the face-cover and the open passage-way. The passage-way is inclined, having the same slope as the crest of the caponier. It is represented in projection by drawing through the foot of the wall at the end of the ravelin face a line parallel to the magistral of the face-cover, and by drawing a line for the inner

side next to the face-cover, parallel to this line and 4.33 yards from it. The slope of the face-cover is arranged so as not to encroach upon the passage-way, or to prevent it from being swept by a fire from the bastion shoulder angle lying upon its prolongation.

The lower end of the passage-way is behind the profile wall of the end of the ravelin face. The upper end is at the foot of the gorge wall holding up the terre-plein of the face of the redoubt of the re-entering place-of-arms next to the bastion. The upper end is masked from an enemy's fire coming from the ravelin in front of its cut by a traverse placed at the upper extremity of the single caponier. Parallel to the magistral of the face-cover and distant from the passage-way sufficient to leave room for the banquette, banquette slope, and base of interior slope of the parapet, a line is drawn to represent the projection of the crest of the caponier. This line, being in the plane passed through the two points of the ravelin ditch and the point *b* of the bastion interior crest, is fully determined when its projection is given.

The lower end of the parapet rests against the scarp wall of the ravelin; the upper end against the traverse used to mask the end of the passage-way.

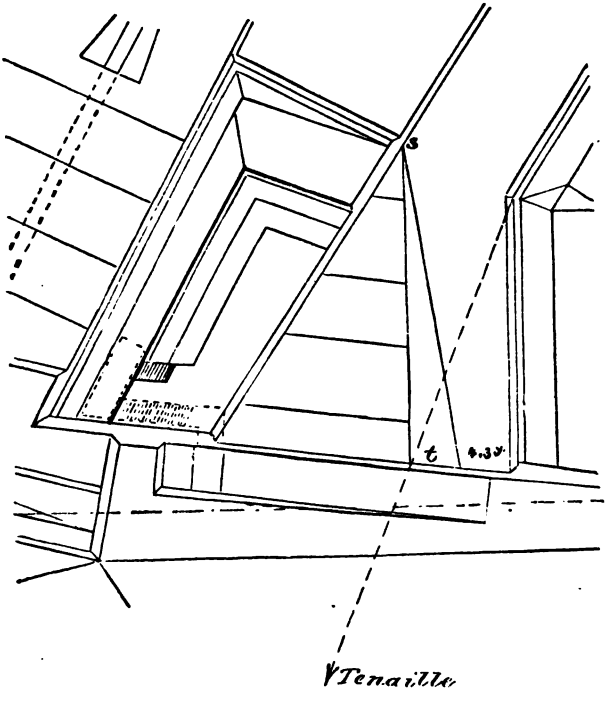
The open passage-way is continued under the face of the redoubt of the re-entering place-of-arms by two posterns, one for artillery and one for infantry, placed side by side, and whose entrances are masked by the same traverse.

The top of the traverse is placed high enough and made thick enough to intercept the fire coming from the ravelin near the cut. A part of the traverse is revetted by masonry, so as to reduce as much as possible the dead space it makes. The portion revetted is shown in Figure 31.

62. Ravelin Counterscarp.—The magistral of the ravelin counterscarp was obtained by drawing a right line parallel to the magistral of the ravelin and 18.0 yards from it.

The counterscarp is revetted, the wall being made 18.0 feet high. The top of this wall should be at least eight feet below the plane of the crest of the covered way next to it. Placing it eight feet below the planes of the crest of the covered way fixes the references of the top of the wall. The height of the wall, the batter, and the position of the magistral being known, the counterscarp is fully determined.

Fig. 32.



The counterscarp wall might have been made of a greater height, but it was not considered necessary to do so, as there is a saving of expense by making it lower.

The ravelin ditch is drained by a small ditch called a **cunette,** one yard wide at bottom, three yards wide at top, and three feet deep. The cunette passes under the single caponier

by a culvert, and empties its drainage into the cunette of the main ditch.

63. Mask in the Ditch of the Ravelin Redoubt.—A mask is placed in the extremity of the ravelin redoubt ditch to cover the masonry of the bastion scarp near the shoulder angle from the fire of batteries that might be placed upon the terre-plein in the salient of the ravelin.

The mask is constructed as follows (Fig. 32):

A right line is drawn from the shoulder angle of the ravelin redoubt magistral to the extremity of the tenaille, and its intersection, *t*, determined with the magistral of the wall holding up the lower extremity of the redoubt ditch. From this point, *t*, to the gorge of the ravelin face, the wall is raised until its top is within 13.0 feet of the terre-plein of the ravelin at the gorge. This raised portion of the wall is protected by an embankment of earth rising to the top of the wall and having its upper surface swept by the fire of the bastion. This is effected by holding this upper surface in a plane passed through the top of the wall it protects and a point, *s*, of the redoubt ditch under the scarp of the cut.

The embankment on one side is held up by the gorge wall of the ravelin face, and on the other by an earthen slope arranged to terminate 4.33 yards from the scarp of the redoubt. This distance is for the purpose of not interfering with the use of the bottom of the ditch as a roadway. The height of thirteen feet from the top of the mask to the terre-plein is in compliance with the rule adopted for the least height of wall to make the ravelin face secure from assault. If the surface of the mask is obliged to be placed nearer than this distance of 13.0 feet to the terre-plein of the ravelin face, the proper height of wall can still be obtained by raising the gorge wall higher and sloping the terre-plein from it—an expedient quite frequently adopted.

64. Bottom of Main Ditch.—When the heights of the

scarp and counterscarp walls were fixed, the general depth of ditch became fixed. The bottom of the ditch is arranged to conform to the heights given to the scarp and counterscarp, and also to keep the ditch dry.

For the purpose of keeping the bottom dry, a cunette, two yards wide at bottom, four yards wide at top, and three feet deep, is made in the middle of the ditch, its direction being parallel to the face of the bastion. The slopes of the sides of the cunette are $\frac{1}{1}$. It passes under the double caponier by a culvert.

The bottom of the ditch from the foot of the scarp to the cunette is sloped so as to give a fall of one foot and a half in that distance. From the foot of the counterscarp to the cunette it has a slope with an inclination equal to the difference of height between the cunette and the foot of the wall.

It will be remembered that the bottom of the ditch in front of the curtain is sloped so as to have a fall of one foot and a half from its middle point to the ends of the curtain, and also to have the same fall from the curtain to the shoulder angles. All these slopes are for the purpose of keeping the main ditch dry.

The slope from the counterscarp to the cunette is considered to add to the difficulties of an assailant in his attempt to cross the ditch, by exposing his trenches more than they would otherwise be if the bottom had a less slope; the slope from the face to the cunette has the effect of making the breach in the bastion scarp steeper than it would be otherwise.

65. Communications.—The terre-plein of the main work is reached from the parade by means of ramps (Fig. 17) connecting the parade and terre-plein. Where room is of great importance, communication with the terre-plein may be had by flights of steps that can be used by foot troops.

A postern under the middle of the curtain affords communication between the interior of the main work and the bot-

tom of the main ditch. This postern is made large enough to be used by all arms of service, and has its entrance to the ditch at least six feet above the bottom of the ditch. This entrance is connected with the bottom of the ditch by a wooden ramp that can be quickly removed or destroyed.

The dimensions of the postern should not be less than **twelve** feet wide and **ten** feet high under the keystone of the arch. The roadway of the postern should be made with as gentle a slope as circumstances will admit, never exceeding $\frac{1}{8}$, and be provided with horizontal landings at the ends. The sides of the cut in the rampart slope, on each side of the entrance to the parade, should be sustained by wing-walls. Door-ways, not less than 7.50 feet high and 7.0 feet wide, should be built at both entrances.

The doors are each composed of two leaves, loop-holed and provided with secure fastenings.

The door-way of the entrance next to the ditch is provided with a draw-bridge that can be drawn back, cutting off communication with the wooden ramp. The bridge is ordinarily made to revolve on a horizontal axis, and when removed from its position is made to fill a recess in the scarp wall and to close the entrance of the postern.

From the foot of the wooden ramp the roadway leads under the tenaille by a postern and into the double caponier.

Flights of steps, placed in the gorge (Fig. 30), are used to reach the terre-plein of the tenaille from the main ditch.

Crossing the main ditch, the lower terre-plein of the ravelin redoubt is reached by flights of steps in its gorge; the upper terre-plein is reached by ramps (Fig. 20).

The ditch of the ravelin redoubt is connected with the bottom of the main ditch by a postern under the flank of the redoubt. The bottom of the redoubt ditch forms a roadway to reach the ravelin, and ramps lead from this ditch to the terre-plein of the ravelin.

The terre-plein of the ravelin in rear of the cut is reached by a ramp beginning in the bottom of the main ditch near the extremity of the flank of the redoubt, and by a winding postern and stairs under the terre-plein and parapet of the extremity of the ravelin. This ramp rises from the bottom of the main ditch until it reaches a height of thirteen feet above the bottom, and is then made level for a short distance, as a landing, in front of the entrance to the postern. This landing is separated, by a break 13.0 feet wide, from the roadway beginning at the end of the ravelin face and passing behind the single caponier. This break is arranged with a draw-bridge, so as to open or close the communication at will (Fig. 32).

The ramp rising from the bottom of the ditch behind the ravelin, the draw-bridge across the break, and the roadway behind the single caponier are used to reach the ravelin ditch, and the re-entrant place-of-arms.

Passing around the traverse at the end of the single caponier, communication is had with the bottom of the ravelin ditch. A flight of steps at the end of the redoubt of the re-entering place-of-arms connects the ravelin ditch with the ditch of the redoubt (Fig. 31).

The entrances of the two posterns under the redoubt of the re-entering place-of-arms are opposite to the end of the open passage-way behind the single caponier. The posterns are under the terre-plein and parapet of the redoubt, and are used to reach the re-entrant place-of-arms. The smaller postern has a branch which, with a flight of stairs, gives access to the terre-plein of the redoubt.

Flights of steps are placed in the salient of the ravelin ditch to connect the ditch with the salient place-of-arms.

Outlets, called **sortie passages**, are made in the re-entering places-of-arms and in the long branches of the covered way between traverses 3 and 4. These outlets afford communication between the covered way and the glacis, and are made

not less than ten feet wide. The bottom of the outlet, or roadway leading through the cut in the parapet of the covered way, is to all intents and purposes a ramp. The sides of the cut are sustained by masonry walls. The outlets are provided with strong barriers arranged to open and shut easily.

66. Remarks upon the Details of the Trace.—The method of determining the magistral, of fixing the position of the interior crest, the width of the terre-pleins, and the means of communication from one part of the work to another, have all been described. To complete the details, the foot of the scarp, of the counterscarp, the interior slope, the banquette slope, etc., should all be represented. As these lines are all parallel to some one of the lines already constructed, it is not necessary to represent them in the figures explaining a construction. They should be represented, however, upon a complete drawing, and their references given when the trace is fully represented.

These lines are represented in Figures 33 and 34. Figure 33 represents the trace of the main work and of the outworks in the main ditch of half of a front, fortified according to the rules of the bastion system.

Figure 34 represents the trace of the outworks beyond the main ditch for the same half front.

Figure 35 represents the profile made by a plane passed perpendicular to the bastion face and the covered way of the bastion. This profile is used for Figures 33 and 34, and is the one used in works where the details of the parapet are left unfinished.

It differs from the profile used in describing the front in having an intermediate level between the terre-plein and the banquette tread. The interior slope is left at the inclination of the natural slope of the earth; the banquette tread is two feet wide; the banquette slope is $\frac{1}{1}$; the intermediate level is two feet and a half below the banquette tread, is six feet wide, and connected with the terre-plein by a slope of $\frac{1}{1}$.

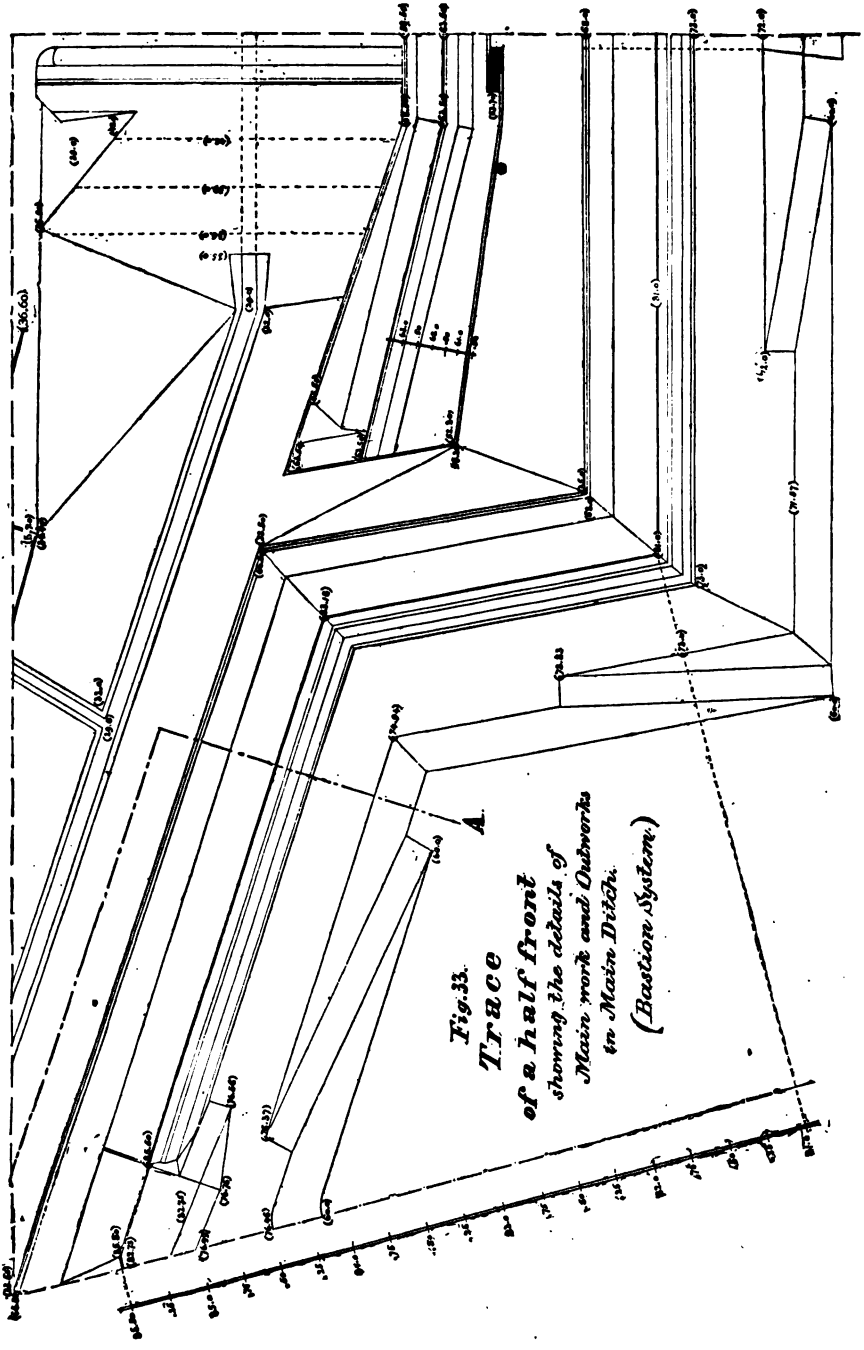


Fig. 33.
Trace
of a half front
showing the details of
Main work and Outworks
to Main Ditch.
(Bastion System.)
A

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INTERIOR WORKS.

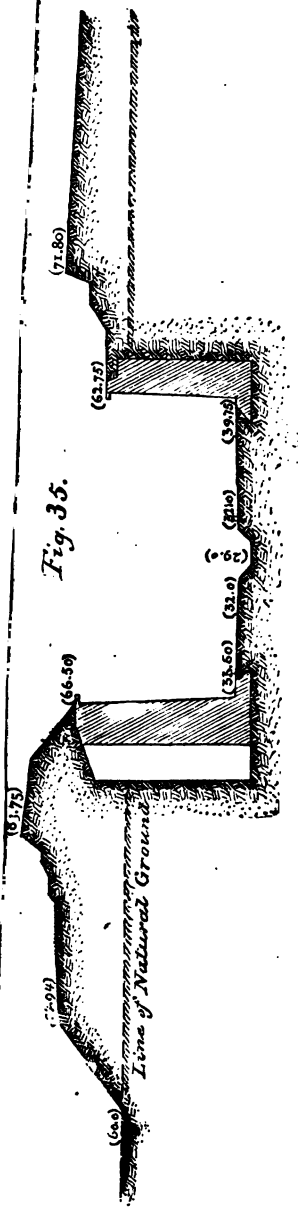


Fig. 35.

Section on Line A, B. of Figs. 33 & 34.

67. Interior Retrenchments. — The main work forms a line of defence and is made continuous. A break in this line weakens the whole, and in many cases causes the whole line to fall when one part is taken. To guard against such disaster, engineers have placed within the main work, other works having for their object the prolongation of the defence. These works are known as **interior works**, because of their position with respect to the main one.

Interior works are divided into three general classes, viz.: **interior retrenchments, cavaliers,** and **citadels.**

Interior retrenchments are the interior works intended to defend breaches that may be made in the main work. These works may be either temporary or permanent. Temporary retrenchments are recommended when there are no permanent ones, but simply because they may be made to prolong the de-

fence. To build them after a siege has begun, will be to expose the men to the besieger's fire, and to add to the labors of the troops, who will want all their strength to make a vigorous defence, and who can ill afford to expend it upon labors that should have been performed in advance of the immediate necessity for the works.

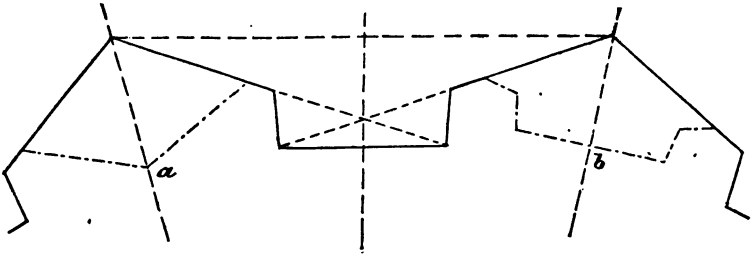
Interior retrenchments are of various forms; the form depending upon the position of the work and the object to be attained by it.

They are constructed, when permanent, in accordance with the general rules used for outworks, being made strong enough to be secure from open assault.

As the bastion is the part of the front most liable to be breached, the interior retrenchment may be placed in the bastion, or in its gorge.

Bastions are made either **hollow** or **full.** When the terre-plein remains as shown in Figure 33, the bastion is said to be hollow; if the whole interior space of the bastion be filled up to a level with the terre-plein, it is said to be a full bastion.

Fig. 36.



The form and position of a retrenchment will be influenced by the consideration of whether the bastion is full or hollow. Full bastions are more easily retrenched by temporary works than hollow ones.

Interior retrenchments may be of four general kinds, viz. (Figs. 36 and 37):

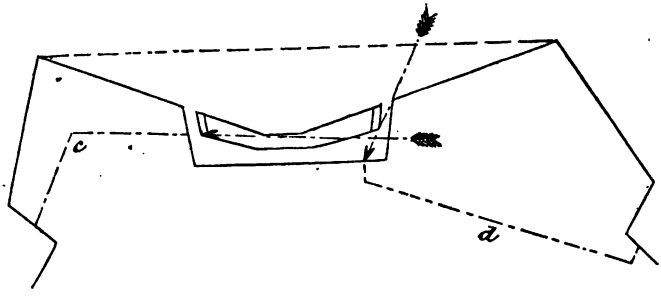
1. Retrenchments having their extremities resting against the faces of the bastion;
2. Those resting against the flanks;
3. Those closing the gorge of the bastion;
4. Those enclosing two or more bastions.

If the breach in the bastion is likely to be made at or near the salient, the interior retrenchment will be one of the first kind, and may have the form of an inverted redan, as *a* in Figure 36, or if the bastion be a large one, the form of a bastion front, as *b*.

Retrenchments of this kind would not be used if there is any danger of a breach being made in rear of them.

If it is probable that the breach will be made at the shoulder angle, the retrenchment would be one of the second kind. The form of the retrenchment in this case might be that of an inverted redan or a bastion front, as in the case where the extremities rest upon the faces of the bastion, or it might be a redan, like *c* in Figure 37.

Fig. 37.



The advantage of the last form is in the direction of the faces of the redan that allows its ditch to be swept by fire from the adjacent bastions, cuts being made in the scarp for this purpose.

If it is probable that the breach will be made at or near the curtain angle, the third kind of retrenchment would be employed. The particular form would depend upon the length of line to be used, and the position of the breaches. The retrenchment might have the form of a simple line with two small flanks, as shown at *d* in Figure 37, or it might be that of a bastion front.

If two or more bastions are to be isolated, the fourth kind of retrenchment would likely be employed.

68. Cavaliers.—It is oftentimes extremely desirable to obtain a plunging fire upon the besiegers' trenches near the main work. The relation existing between the relief and the lengths of the parts of the main work prevents the use of the main work for this purpose, and compels the employment of an additional work. This interior work used to obtain a plunging fire upon the glacis is called a **cavalier.**

The cavalier is also useful as a traverse to defilade parts of a work from an enemy's fire. It may be placed for this purpose upon the curtain or in a bastion. It is usually placed in a bastion and given the form of a lunette, its faces and flanks being made parallel to the faces and flanks of the bastion.

When placed in a bastion, it is usual to isolate the cavalier from the salient portion of the bastion by cuts made either in the faces or in the flanks of the bastion. Parapets are arranged behind these cuts, connecting the faces or flanks of the bastion, as the case may be, with the cavalier.

These parapets and the faces of the cavalier are used as an interior retrenchment to defend a breach that may be made in the bastion salient.

When the cavalier is isolated by cuts made in the flanks of the bastion, a direction is given to the faces of the cavalier and the cuts that will allow them to be swept by the fire of the flanks of the adjacent bastions.

69. Citadels.—Any interior work that is independent of the main work, organized to receive a garrison and expected to rely on its own resources after the main work has fallen, is known as a **citadel.**

CHAPTER V.

OPEN AND COVERED DEFENCES.

70. Open Defences.—The arrangements made by which the soldier is protected from the enemy's direct fire are known as **open defences.** The simple earthen parapet arranged so that the soldier can fire over it, and so that, by stepping back upon the banquette slope, or crouching behind the interior slope, the soldier can be protected from the direct fire of the enemy, is an example of an "open defence."

71. Barbettes.—To allow cannon to fire over a parapet some arrangement must be made to raise the gun into a position from which its line of fire will pass over the parapet.

This may be effected by using a carriage which elevates the gun when desired, or by building a mound of earth behind the parapet, on the upper surface of which the gun can be placed. This latter arrangement is called a **barbette.**

The barbette rests against the interior slope, and its sides are given the natural slope of the earth. Its upper surface is level, near enough to the interior crest to allow guns on the barbette to fire over the parapet, and connected by ramps with the terre-plein. The barbette may be made only large enough for one gun, or for a greater number.

Barbettes are especially useful in case of an assault in salients, where by their use they give a wider field of fire.

They have the serious defect of exposing the guns, and the gunners serving the pieces, to the enemy's fire.

72. Embrasures.—An **embrasure** is a cut made in a parapet through which a cannon can be fired upon the ground in front of it.

The opening in the interior slope of the parapet is called the **throat**; the sides of the cut are termed **cheeks**; and the bottom, the **sole** of the embrasure.

The sole of an embrasure is ordinarily inclined so as to allow the gun to be fired at a depression, and generally is made parallel to the superior slope of the parapet. The sole widens from the throat to the exterior slope, to give a larger field of fire to the gun. This widening of the sole is termed the **splay.**

The throat is made just large enough to admit the muzzle of the cannon, and is made either rectangular or trapezoidal in form.

The embrasures are said to be **direct** when the middle line of the sole is perpendicular to the interior crest; when not so, the embrasures are **oblique.**

The portion of the parapet between two consecutive embrasures is called a **merlon.**

Embrasures give a limited field of fire, afford good marks for the enemy, and require frequent repairing when in use. They afford better cover than the barbette for the gun, its carriage, and the gunners, especially against the fire of small-arms.

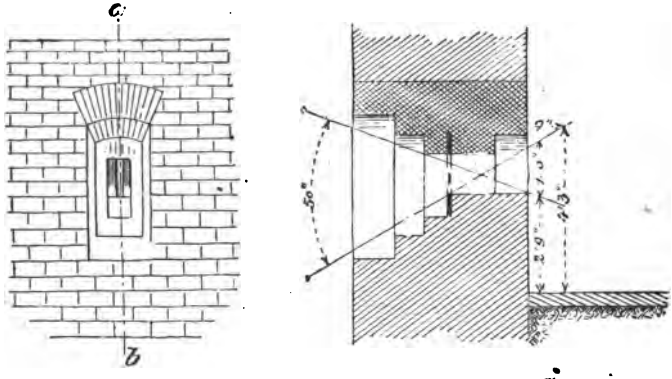
When the field of fire is a limited one, like that of flanking a ditch, or when the embrasure will not be exposed to the enemy's direct artillery fire, an embrasure can be usefully employed.

73. Loop-holed Walls.—Masonry walls, like those represented in Figures 6 and 7, are usually placed in a defensive condition by providing them with apertures through which a fire of small-arms can be had upon the ground in front of the walls. These apertures are made of sufficient size to admit the muzzle of the piece, and are called **loop-holes.**

The loop-hole is a narrow slit in the wall, the dimensions of which will depend upon the field of fire to be obtained and upon the thickness of the masonry.

If the wall is a thin one, that is, its thickness does not exceed 2½ feet, the slit is made on the face of the wall, and about two inches wide and twelve inches long. The top, bottom, and sides of the loop-hole joining the slit with the back of the wall are made sloping, to give the required field of fire. Horizontal and vertical sections, made through a loop-hole of this kind, would be trapezoidal in form. If the fire through the loop-hole was one of considerable depression, the length of the slit would be vertical; if the depression required was slight, and the fire was one of considerable extent laterally, the length of the slit would be horizontal.

Fig. 38.



Front Elevation. *Vertical Section.*
(Section on line, a, b.)

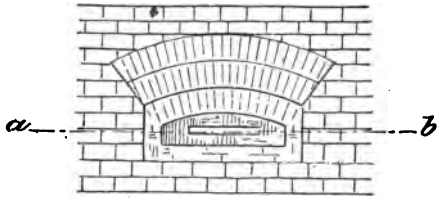
If the wall was of medium thickness, the slit or throat of the loop-hole would be placed about two feet from the back of the wall; the sections of the loop-hole from the throat to the back of the wall would be trapezoidal; from the throat to the face of the wall, the sections would be rec-

tangular. The exterior rectangular opening is made large enough to allow full room for the field of fire obtained by the loop-hole in rear of the slit. When the wall is a thick one, the exterior opening is made in offsets.

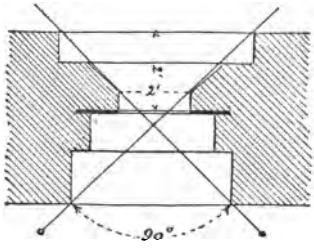
Figure 38 represents the front elevation and vertical section of a loop-hole made in a thick wall where considerable depression of the piece is required.

Figure 39 represents the front elevation and horizontal section of a loop-hole where a wide horizontal field of fire is desirable.

Fig. 39.



Front Elevation



Horizontal Section
(Section on line, a, b.)

The slit or throat of the loop-hole, in each of these examples, is made of iron plate, with an aperture two inches wide and twelve inches long, placed at such a level that the line of fire of greatest depression shall not be higher than the shoulder of a man standing at the loop-hole to use it.

The distance of the loop-hole above the exterior foot of the wall should not be less than *six* feet. If this distance is less, a ditch of sufficient depth should be dug at the foot of the wall to place the loop-hole not less than six feet above the ground at the base of the wall where an enemy could stand.

The loop-holes are placed from three to four feet apart, the distance depending upon the thickness of the wall.

74. Machicoulis.—When the line of fire is required to

be one with a large angle of depression, the vertical loop-hole fails to furnish it. Another method has to be used to get the field of fire when the angle exceeds 30° with the horizontal.

The method employed in the older fortifications, was to build into the scarp wall near its top a row of corbels or strong brackets. On these corbels or supports a parapet wall was built, with its back projecting beyond the face of the scarp wall. This parapet wall and the top of the scarp wall formed an open gallery. In the bottom of this gallery, between the parapet wall and the top of the scarp wall, loop-holes were made with slanting directions such as to give lines of fire reaching the foot of the scarp wall and such other points as were not seen by other flanking arrangements.

Arrangements of this kind having for their object to provide a fire in which the angle of depression is a great one, are known as **machicoulis**, or "machicolated arrangements."

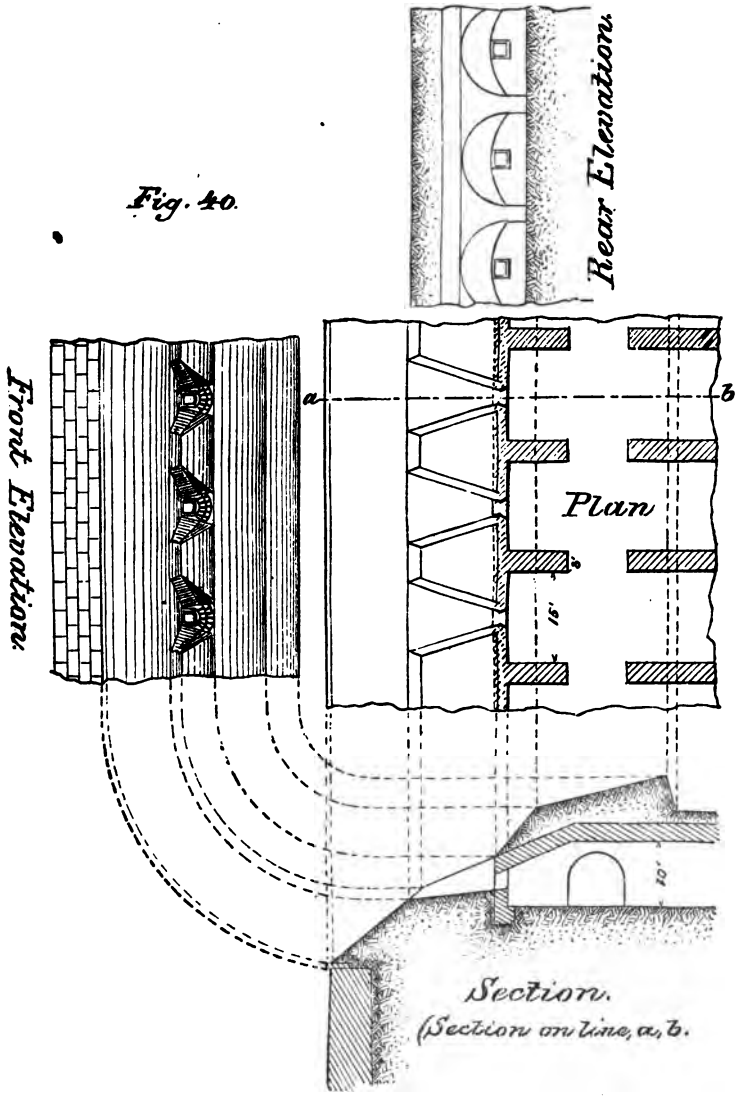
Sometimes, for the purpose of obtaining this fire of great depression, small polygonal constructions, with the sides and bottom provided with loop-holes, were built projecting over the scarp wall, at the angles of a work not exposed to artillery fire.

75. Covered Defences.—Open defences are intended to protect only from direct fire. Defences that protect from **curved** and **vertical** fire are termed **covered defences.**

Protection from vertical fire is ordinarily obtained by placing the thing or person to be protected under a bomb-proof roof, and then arranging the shelter so that it can be used defensively. Rooms with bomb-proof roofs prepared so that artillery can be used in them are known as **casemates**; when they can be used only for the fire of small-arms, they are termed **galleries.**

76. Casemates along the Parapet.—Casemates placed along the parapet of a work require that openings be made in

the parapet, through which a fire can be had upon the ground in front from the guns in the casemates.



The general form of casemate of this class is that devised by General Haxo, of the French engineers. The **Haxo case-**

mate is an arched chamber of masonry made bomb-proof by a covering of earth (Fig. 40).

The wall forming the front of the chamber is masked by the earth of the parapet, excepting a small portion above the muzzle of the gun. The opening through the front wall for the muzzle of the gun is made upon the general plan of a loop-hole. From this opening to the exterior slope of the parapet, the simple embrasure is used.

The roof of the chamber is a masonry arch covered with earth to make it bomb-proof. The piers of the arch form the sides of the chamber, and have arched door-ways made in them to allow communication between the casemates, and to give a larger traverse to the gun when fired. The rear end of the chamber, when the casemate is used for the gun alone, is left open to allow free escape for the smoke.

The arched roof for a distance of 10.0 feet from the front wall inclines downward, so as to leave at the muzzle of the gun only sufficient height of chamber to work the gun. This reduction of height reduces the amount of masonry of the front wall exposed to fire by the embrasure in front of it. It is proposed to protect this exposed masonry by iron shields, or by heavy timbers placed across the throat of the embrasure.

The casemate has an inside width of 15.0 feet; and an interior height under the crown of the arch of 10.0 feet. The length of the casemate will depend upon whether it is to be used for the gun alone, or whether there is to be an additional use made of it.

These casemates may be placed along the parapet, as in the case of ordinary embrasures, or they may be built in traverses used to defilade the terre-plein.

77. Casemates along the Scarp.—Casemates along the scarp were much used in the older fortifications, especially in those exposed only to a naval attack. In these fortifications,

the thick scarp walls were considered to be less vulnerable than the sides of the ships making the attack, and this consideration justified the use of masonry.

The casemates were vaulted chambers of masonry, with their floors on a level with the parade, and their roofs supported the terre-plein and parapet of the work. They were ordinarily made two rooms deep; the one next to the scarp being used for the gun; the one in rear, or next to the parade, being used for quarters, for a store-room, etc.

Since the scarp wall was very thick at the level of the parade, an arched recess was made in the back of the scarp wall, reducing its thickness to something less than six feet. The opening in the wall for the gun, or **gun-port**, was placed in the centre of this recess, and its sides were given slopes such as would allow the gun a traverse of 60°. The throat was placed about two feet from the face of the scarp, and made large enough to admit the muzzle of the gun. In the older works, the plan of the gun-port was trapezoidal on both sides of the throat. In the later works, it was trapezoidal in rear of the throat and rectangular in front of it. The gun-port of twenty years ago, used in the fortifications of that time, was that devised by the late General Totten, Chief of Engineers of the United States Army. The plan was trapezoidal in rear, and rectangular in front of the throat. The opening in the throat was two feet high and nineteen inches wide. The throat pieces were of wrought iron eight inches thick. These pieces were trapezoidal in plan, with the longer side eighteen inches long. The oblique side of the base had the same slant as the inner cheek of the gun-port. Exterior to the throat pieces two pieces of plate iron were placed, against which iron shutters two inches thick rest, when open or shut. The shutters when open were in the rectangular recess out of the way of the gun; when shut, they closed the throat, and were strong enough to resist canister or grape. A wrought-

iron casing, 11.0 inches wide, was placed on the face of the wall, around the exterior opening of the gun-port.

This form of gun-port was a great improvement upon those preceding it. The construction, however, does not possess sufficient strength to resist the projectiles now used.

78. Iron Shelters.—Iron has had a limited use in Europe in forming covered defences for heavy guns. **Iron turrets** armed with two guns and made to revolve, have been placed on some of the works at points where it is necessary to have a distant and wide field of fire. The iron turret furnishes the shelter, and also gives all the advantages of barbette fire without its exposure.

Iron Shields are also used to strengthen the Haxo casemate. These shields may be built up of iron plates, or may be of one solid piece. Sometimes the shield has more than one gun-port, in which case it is made curved in plan. The gun can be fired through either of the ports by traversing the chassis. The casemate itself may be made of iron, the roof being made of curved iron plates, and the supports of iron pillars. A casemate of this kind can be made of much less height than one made of masonry. The cost of iron defences, the best forms to give the shields, the best methods of making them, the difficulties of fastening them into the parapets, etc., are questions to be considered in the use of iron. These questions are now being examined by the best minds of the engineering profession.

79. Mortar Casemates.—Casemates for mortars are also used in permanent works. In construction and object they do not differ from gun casemates.

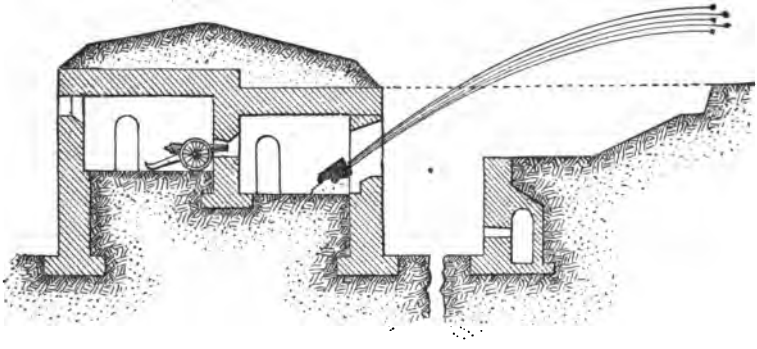
Mortar casemates are placed in traverses, under the ramparts, and on the parade. They may be placed almost anywhere, provided they do not occupy space that may be needed for cannon.

When made of masonry, the latter should be masked from

the enemy's fire. In some cases, the whole front of the chamber is left open, being sheltered by something in front of it.

Figure 41 is an example of a casemate in rear of a salient place-of-arms with a gun-chamber in rear of it. The gun has

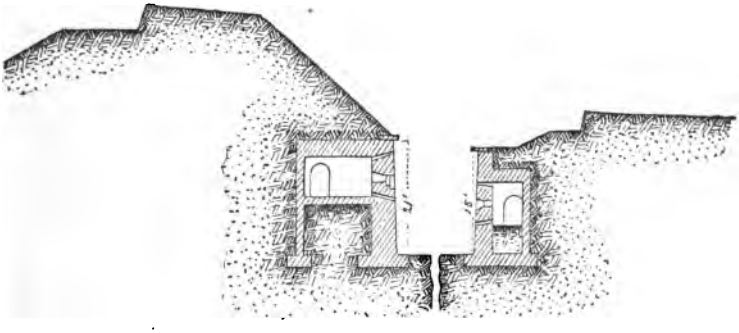
Fig. 41.



a fire through the mortar casemate upon the terre-plein of the salient place-of-arms.

80. Scarp and Counterscarp Galleries.—When reliev-

Fig. 42.



ing arches are used with scarp and counterscarp walls (Figs. 4 and 5), it is usual to make loop-holes in the walls for musketry (Fig. 42). These covered defences are termed **galleries,**

and receive the name of scarp or counterscarp galleries according to the kind of wall behind which they are placed.

These galleries are useful to furnish a fire along the ditch as well as across it, and are useful adjuncts of the flank defences of a fortification. Counterscarp galleries are, in addition to the fire they give along the ditch, useful in countermining operations. In turn, however, they become useful to the besieger if he gains possession of them.

81. Detached Scarp Walls.—Under the head of open defences, loop-holed walls are mentioned. These were arranged to afford protection only against direct fire. Partial protection against vertical and curved fire may be obtained, when the wall is a thick one, by making arched recesses which shall be deep enough to give the men shelter. These recesses will also afford protection against a fire coming along the back of the wall.

82. Traverses.—Traverses are especially needed upon the faces of a work exposed to enfilade fire. They are also essential upon faces where the fire is very oblique, and are necessary to limit the area of destructive effect from fragments of bursting shells.

The traverses should be made high enough and thick enough to intercept the projectiles, and placed near enough together to limit the area of exposure to fragments of shells.

It is recommended to keep the top of the traverses on a face exposed to enfilade within three feet at least of the interior crest. A height greater than this has the defect of pointing out the position of the guns to an enemy.

The length of a traverse is determined by the lines of fire it is intended to intercept and the space it is to protect. They are usually made from 24.0 to 30.0 feet long.

On faces exposed to enfilade, only one gun is placed between any two traverses; on other faces, not more than two guns are mounted between two traverses. The room required for the

service of the gun will fix the least distance apart of the traverses.

Traverses are further utilized by building them hollow, and constructing within them bomb-proof shelters for guns, the gunners, etc.

Where masonry is used, the thickness of the arch forming the roof of the shelter should not be less than *three* feet, and the thickness of the earth covering not less than *six* feet, to make the roof bomb-proof. The thickness of the earth protecting the sides of the shelter should not be less than *ten* feet.

A traverse having for its object the protection of a given area from reverse fire is termed a **parados.**

A shell passing over a parapet, striking against a parados and exploding, throws back splinters from the parados. To prevent the injurious effects of these splinters, experiment has shown that the foot of the parados, in rear of a gun which it protects from reverse fire, should be at least twenty yards from the rear end of the gun platform when the projectiles are those of siege or field guns, and not less than thirty yards when the projectiles are from heavier guns.

It is also found that the best material of which to construct the parados is earth, free from stones and gravel.

83. Magazines.—Powder magazines, store-rooms for the different kinds of ammunition, and rooms in which the shells can be filled and the ammunition made up must be provided and should be made bomb-proof.

The **main powder magazines** are placed in the most sheltered and the most convenient situations that can be found for them. The interior of these structures, the doors, windows, floors, etc., are all built with a view of making the magazine fire-proof. No steel or iron should be used in their construction.

The walls are made hollow to prevent dampness, and are arranged with flues for ventilation. The flues have their

directions broken, and all apertures or air openings are protected by copper network to prevent rats, mice, combustible materials, etc., from reaching the interior.

Care is taken to exclude the outside air from entering the interior directly, excepting when the temperature and dryness of the air are such as to absorb the moisture rather than deposit it on the walls of the interior.

Besides the main powder magazines, smaller ones are built in the rampart under the terre-plein, in which ammunition can be prepared and stored for the guns of the battery over them. These are known as **service magazines**, and also as "expense magazines."

When there are hollow traverses over them, the service magazines are made to communicate with the traverses by stairs, or lifting apparatus, etc., under the terre-plein. The ammunition can then be carried from the magazine to the traverse without exposure to the enemy's fire. Sometimes a traverse on the terre-plein is made a service magazine large enough to contain a twenty-four hours' supply of ammunition for the guns next to it.

Ammunition **recesses** are made under the parapet to contain ammunition for immediate use in case of an assault. The entrance to the recess is in the interior slope, and is arranged so as not to interfere with the firing over the parapet.

84. Bomb-proof Barracks and Shelters.—An enemy will, in his attack of a fortified place, usually try the effect of a heavy bombardment before he begins work upon the trenches. In many cases, the heavy bombardment has had the effect of compelling the garrison to surrender, mainly due to the want of bomb-proof shelters.

To have a garrison make a vigorous defence, it is essential that safe shelters should be provided in which the troops off duty can obtain an unbroken rest. For this reason, bomb-proof barracks are built in permanent works. The casemates under

the terre-plein may be fitted up as barracks, or the barracks may be constructed independent of the defences of the work. In the latter case, the buildings should be placed where they will not be exposed to a direct or reverse fire of the enemy and must be made bomb-proof. It is usual to arrange the barracks for defence by making loop-holes in the walls, and in many cases prepare them for artillery defence. When the casemates are used as quarters, allowance should be made for a part of them becoming untenable during a siege.

Ample covered quarters and store-rooms should be provided in advance of their need, although they may be supplemented by blindages when placing the work in readiness for defence.

85. Advantages and Defects of Covered Defences.—The great advantage of well-constructed covered defences lies in the protection they afford the guns and gunners against curved and vertical fire. The improvements made in fire-arms and the introduction of rifled cannon have made shelter from vertical and curved fire an absolute necessity. However, the defects of covered defences are of considerable magnitude. They limit the field of fire of the gun, they limit the field of view of the gunner, and the smoke of the gun when fired fills the gallery or casemate and hangs around the port or loop-hole, obscuring the view of the defence. These inconveniences were felt to be so important in the past that covered defences were much less used then than they will be in the future. Attention will be paid to ameliorating or removing these defects, and methods devised to reach objects in range of the gun by its fire, whether they can be seen or not.

CHAPTER VI.

MODIFICATION OF THE BASTION SYSTEM.

86. Importance of the Bastion Trace.—The bastion system of fortification has been the principal system employed on this continent during the past. Whether it is in the future to remain a prominent system, or to disappear, is a question which time can only answer. It is certain, however, that there are many works constructed upon the bastion trace that in time of peace will be repaired or ameliorated, and in war will be attacked and will be defended. It is important, therefore, to the engineer and to the military student that they know the principles of the bastion system and the methods of constructing its trace.

In describing the trace, open defences are the only ones mentioned. It is not meant by this omission of covered defences to imply that they are not to be employed in a bastion trace. On the contrary, they are freely used in recent works, and in works recently modified, that are constructed on the bastion trace.

Haxo casemates are built along the faces of the main work, casemates are constructed in the redoubts of the re-entering places-of-arms, and bomb-proof shelters are freely provided under the ramparts. The situations in which bomb-proof shelters are placed depend greatly upon the nature of the ground in front of a work and upon the direction of the attack.

87. Scarp Wall.—In the construction of the bastion trace,

a height of thirty-one feet and a half was given to the scarp wall at the middle of the curtain. The top of the wall was placed at or near the level of the crest of the covered way.

This height of wall and position of its top are taken in the example, because the older works, as a general rule, have their scarps of this height, and the top of the scarp wall nearly on a level with the crest of the covered way. The height of thirty feet was taken to make the place safe from escalade; the top of the wall was made as high as possible for the purpose, while being screened by the covered way, of bringing the interior crest of the work nearer to the glacis, so that this latter would be in close musketry range of the main work.

The improvement in fire-arms, by which the range of the musket is greatly increased, makes this nearness of the interior crest to the glacis less important than formerly. The great importance of sheltering the scarp wall from indirect as well as from direct fire, will cause the top of the scarp wall to be placed in the future at a lower level.

It is probable that in new works constructed on the bastion trace, detached scarp walls high enough to prevent an open assault will be the ones employed. However, there may be cases like those in which the masonry is not exposed to the fire of heavy guns, where the old height of scarp wall may be retained. Or, if exposed to artillery fire and the old height retained, that a glacis will be used in the ditch as a screen for the masonry.

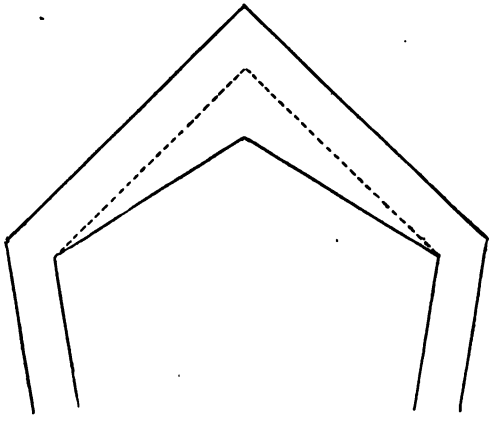
88. Interior Crest.—The interior crest of the older works is parallel, or nearly so, to its magistral, and is so taken in the trace described.

In recent fortifications, this method is not always followed, the interior crest being, in many cases, different in form from the magistral. In the case where the faces of a bastion would be exposed to enfilade, if made parallel to the magistral, the

salient of the parapet may be set back, and the faces directed so that they make an angle at the salient more obtuse than that made by the magistrals of the faces (Fig. 43). In some cases, the interior crest of a face has been made a crémaillère line.

This deviation from the old rule of making the crest parallel to its magistral, originated with Colonel Theodore Choumara, of the French engineers, who wrote and published in 1827 a memoir upon the general principles of permanent fortification. A similar proposition in principle was made by Chasseloup, an older engineer, but not to the extent proposed by Colonel Choumara.

Fig. 43



The latter, in his memoir, divides a permanent work into two parts, an upper and a lower. The lower part, forming an obstacle to assault, consists of masonry not easily modified during a siege, and is considered by him as **permanent.** The upper, forming a shelter, consists of parapets and traverses made of earth easily modified during a siege, and is considered by him as **variable.** He proposes to change the variable part so as to meet the circumstances of each case, and not to have the interior crest parallel to its magistral unless

this position is the best one. This principle of arrangement of the interior crest is called the principle of "**independence of parapets**" with respect to scarps.

89. Command.—The command of the interior crest above the plane of site depends upon the formation of the ground in its front. This ground should be well overlooked by the work.

The command of permanent works will seldom be less than twenty-seven or thirty feet above the plane of site, although a minimum height of twenty-one feet is taken in the trace described.

90. Outworks.—There is a tendency toward simplifying and reducing the number of outworks. The importance of the rampart of the main work, as the main line of defence, has been greatly increased by the improvements made in cannon. Any outwork that interferes with the defensive properties of the main work is to be regarded now as of doubtful utility. Outworks should not, therefore, interfere with the fire of the main work, and should be carefully planned with that object in view.

91. Modification of the Trace.—The bastion trace was modified by Vauban. His method was improved upon by Cormontaigne. The modern trace is the improvement made upon Cormontaigne's method. Belidor, Robillard, Marshal Saxe, La Chiche, Montalembert, Bousmard, Chasseloup, Carnot, Noizet, Dufour, Choumara, Haxo, and many others have proposed alterations in the bastion trace, and suggested modifications in existing fortifications. Some of these modifications have been tried; others exist only on paper.

These modifications are given in the histories of permanent fortification, and are interesting as showing the changes proposed from time to time, and the views held by the best engineers of their day.

The bastion trace constructed by Vauban is the type of fortification in existence at the close of the 17th century.

Vauban is credited with systematizing the rules of the bastion system, and making the bastion trace applicable to the site to be fortified. Engineers who lived after him studied his works, analyzed his constructions, and divided his traces into three classes, which are known as **Vauban's First, Second, and Third Methods** of fortification.

The earlier traces used by Vauban belong to the **first** method; the traces used by him to fortify Belfort and Landau, belong to his **second**; and the trace he employed at Neuf Brisach belongs to his **third** method.

An examination of the trace first used by Vauban, and that employed by Cormontaigne, will show the changes made in the bastion trace since its general adoption for fortifications.

CHAPTER VII.

VAUBAN'S FIRST METHOD.

92. Trace.—The trace of a fortification, according to Vauban's First Method, is given in Figure (44). This trace is a mean of his earlier works, showing both the straight and the concave flanks with the orillon that he sometimes used.

Orillons were used by engineers who preceded Vauban, but they had gone out of use when Vauban restored them. He afterwards discarded them from his works.

Vauban is credited with being the first engineer to use the tenaille in the main ditch as a mask for the curtain.

93. Construction of Trace of Main Work.—The construction of the trace of the main work is as follows:

The exterior side is 189 toises long; the toise is equal to six feet and four-tenths of a foot (6′.4). At the middle point of the exterior side a perpendicular is drawn. Upon this perpendicular within the exterior side, a distance of one-sixth of the exterior side is laid off, if the circumscribing polygon is a hexagon or a polygon of a greater number of sides; one-seventh, if a pentagon; and one-eighth, if a square.

This distance of one-sixth, or 30 toises, determined the position of the point T (Fig. 44) through which right lines are drawn to the salients, *a* and *b*, determining the directions of the faces. The faces are each made 50 toises long, or about two-sevenths of the length of the exterior side.

The flanks when straight are chords of arcs determined as follows:

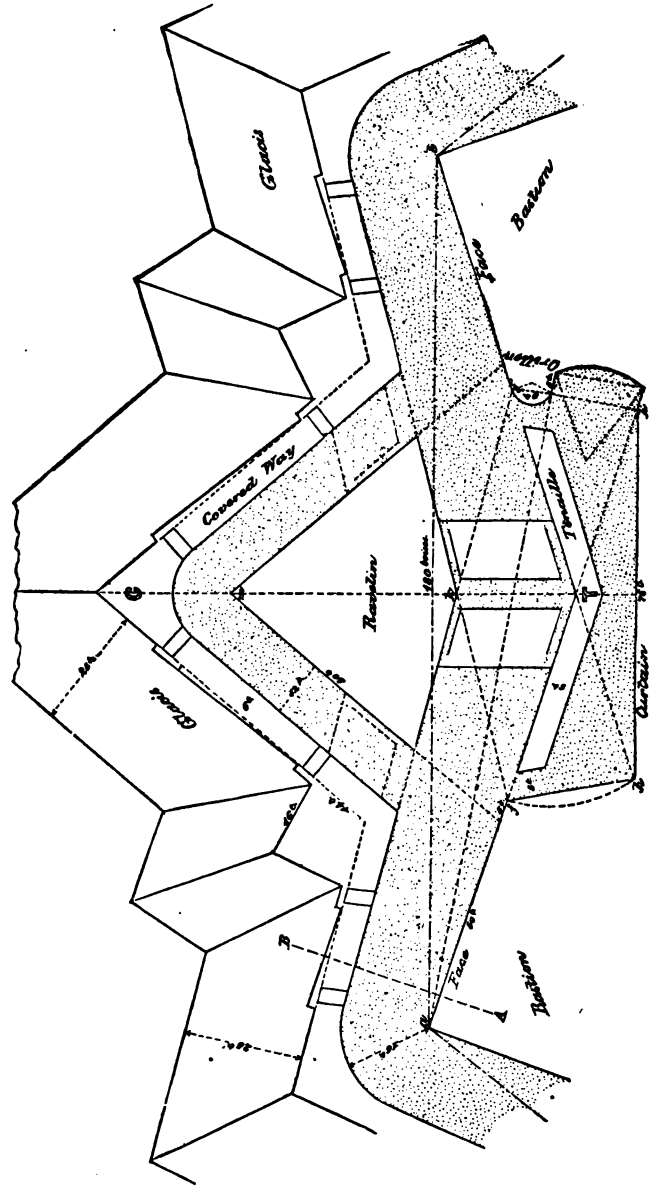


Fig. 44.
First Method of Tracing
Scale: 40 Yards = 1 Inch

Taking the shoulder angles as centres and the distance between them as radii, arcs of circles are described from the

shoulder angles until they intersect the lines of defence; the chords of these arcs, $f\ h$ and $f'\ h'$, are the flanks.

The curtain is obtained by joining the extremities of the flanks by a straight line.

When he used a concave flank and an orillon, the flank in some cases was constructed as follows:

The chord $f'\ h'$ was obtained as just described, and a distance of nine toises laid off from the shoulder angle upon this chord for the width of the orillon. Through this point, nine toises from the shoulder angle, a right line is drawn to the salient of the opposite bastion, and produced within the shoulder angle. A distance of five toises from the chord $f'\ h'$, is laid off on this line produced. This gave one extremity of the concave flank.

To obtain the other extremity of the flank, the line of defence, a T, was prolonged, and a distance of five toises from the end of the curtain laid off upon it; this gave the other extremity.

The two extremities were joined by an arc of a circle of 60°; this arc is the concave flank. The orillon is obtained as follows:

The angle between the face of the bastion and the line joining the end of the flank with the salient, a, of the opposite bastion is bisected; a line is drawn through the shoulder angle perpendicular to the bastion face and its intersection with the bisecting line found; this point of intersection is taken as a centre and its distance from the shoulder angle as a radius, and an arc of a circle described; this arc is the orillon.

94. Main Ditch.—The main ditch is made 16 toises wide at the salients of the bastions. Its counterscarp is circular at the salients; the rest of the counterscarp is tangent to the circular part and directed upon the opposite shoulder angles.

95. Tenaille.—The form of the tenaille was sometimes that of two wings only; at others, two wings and a curtain.

The tenaille was made 6 toises wide, and was separated from the flanks by an interval of 5 toises, and from the curtain by an interval not less than this distance.

Its interior crest was on a level or a little below the plane of site, so as to allow the fire of a gun at the middle of the flank to reach the foot of the scarp of the opposite face near the shoulder angle.

96. Ravelin.—The form of the ravelin in some of Vauban's fronts was that of a lunette; in others, a redan. The dimensions also differed, being greater in some cases than in others.

The salient, *m* (Fig. 44), was sometimes obtained by taking the distance between the shoulder angles as a radius and with the curtain angle as a centre describing an arc. The point outside of the exterior side where this arc cut the perpendicular was the salient of the ravelin.

The method used in Figure 44, to obtain the magistral of the ravelin was to take a point on the bastion face 5 toises from the shoulder angle and to draw a line to the point *m* on the perpendicular, so that the length of the ravelin face should be equal to that of the bastion face, or 50 toises.

The interior crest of the ravelin was placed three feet lower than that of the curtain.

The ravelin ditch was made 12 toises wide and of the same depth as the main ditch. Its counterscarp formed a continuous wall with that of the main ditch.

A small redoubt was placed in the ravelin. In some cases this redoubt was a loop-holed wall with a ditch in front of it, prepared beforehand; in others, it was made of earth after the work had been attacked.

97. Covered Way.—The covered way surrounded the entire counterscarp of main work and ravelin, and was made 6 toises wide.

To construct the re-entering place-of-arms, two points, at 14 toises from the vertex of the re-entering angle made by the crests of the covered way, were taken upon these crests as centres. With radii of 16 toises, arcs were described. The point of intersection of these arcs was joined with the centres, and these lines are the crests of the re-entering place-of-arms.

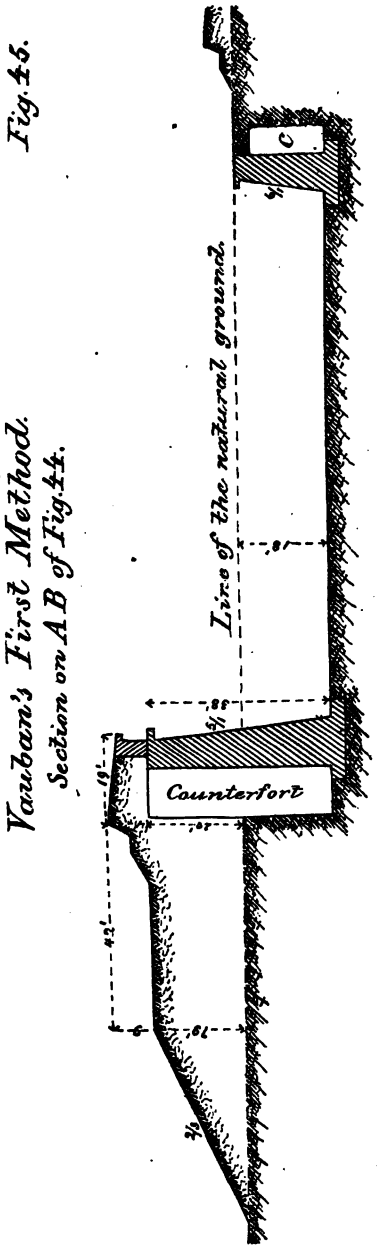


Fig. 45.

Vauban's First Method.
Section on AB of Fig. 44.

The crest of the covered way was given a command of 8.0 feet. The glacis planes were passed through the crests and intersected the plane of site at 25 toises from the covered way.

Traverses were placed on the covered way on the prolongations of the faces of the bastion and ravelin, and where the covered way joins the re-entering places-of-arms. The passages around them were made one toise wide.

98. Caponiers.—A double caponier is placed in the main ditch, affording covered communication across the ditch to the gorge of the ravelin.

Single caponiers, indicated in the figure by dotted lines,

are placed in the ravelin ditch to afford covered communication across that ditch.

99. Profile.—The profile used by Vauban is given in Figure 45; the dimensions being given in (U. S.) feet. The parapet is made 19.0 feet thick; its superior slope is $\frac{1}{6}$; its interior crest is 8.0 above the terre-plein. The terre-plein is 42.0 feet wide and slopes to the rear, having a fall of one foot or a foot and a half in that distance. The rampart slope is $\frac{2}{3}$.

There is no exterior slope to the parapet, the earth being held up by a wall three feet thick and from five to six feet high built on top of the scarp wall.

The scarp wall is made thirty-eight feet high, and has a batter of $\frac{5}{1}$. The bottom of the ditch is 18.0 feet below the plane of site.

The back of the scarp and counterscarp walls is made vertical, and strengthened by counter-forts placed about 16.0 feet apart.

The terre-plein is 20.0 feet above the plane of site; and the interior crest has a command of 28.0 feet.

100. Remarks upon Vauban's Trace.—The construction just given, with an exterior side 180 toises long, gives to the flanks a length of 27 toises each, and to the curtain a length of 76 toises.

From the relation between the parts, it is seen that—

1. The bastions are large and roomy;

2. The length of flank allows as many guns to be mounted upon it as the besieger can place on the opposite glacis to counter-batter it;

3. The length of curtain allows its scarp to be swept by the fire of the flanks;

4. The position of the flanks and the low command of the tenaille allow the scarps of the faces to be swept by the fire of the flanks;

5. The dimensions of the ditches and height of scarp walls present a formidable obstacle to an assault.

It is also seen that—

1. The ravelin is too small to allow a strong permanent redoubt to be built in it to give it the support now deemed necessary when attacked;

2. The ravelin ditch is so wide as to expose the ravelin covered way to slant reverse fires;

3. The ravelin ditch exposes a large portion of the scarp of the bastion face to the fire of the besieger's batteries on the glacis of the salient place-of-arms;

4. The small size of the re-entering place-of-arms prevents the construction of a permanent redoubt in it;

5. The tenaille only partially covers the scarp of the curtain and leaves it exposed at the curtain angles.

It is also seen that the exposure of masonry to fire is increased by using so high a scarp wall, and in using a wall instead of an exterior slope of earth to hold up the parapet.

It is well to remember that Vauban used no arbitrary combination of parts in proportioning the parts of his trace. He varied the lengths and directions of the faces and flanks so as to get the best command over the ground in front and to avoid enfilading fire. His great excellence was shown in the skill he displayed in adapting the bastion trace to the site he proposed to defend. "One does not fortify by systems," he said, "but by good sense and experience." This remark is as true to-day as when he uttered it.

CHAPTER VIII.

CORMONTAIGNE'S METHOD.

101. Cormontaigne.—Cormontaigne, the immediate successor of Vauban, was born in 1696, and died in 1745. He is distinguished for an able memoir on fortification, and for several projects of fortification, among which are the crown-works at Metz.

His writings upon fortification were so clear and complete that they were taken, after his death, as manuals for instruction of the engineer officers of the French army.

The principle laid down that "**all masonry should be masked from the direct fire of an enemy,**" was adopted by Cormontaigne, and formed a leading principle of his method.

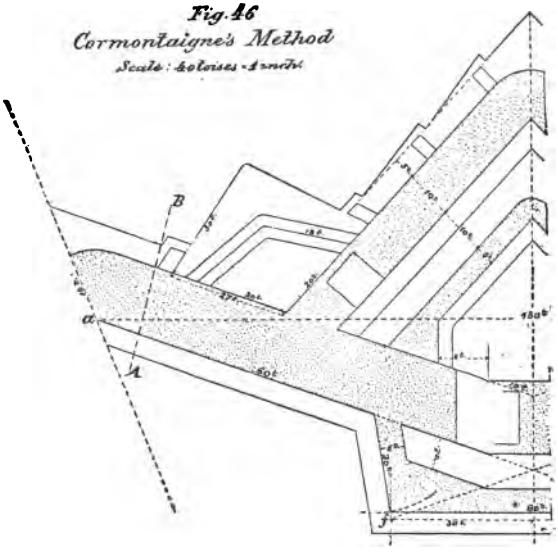
102. Construction of Trace of Main Work.—In Cormontaigne's trace, the length of the exterior side is taken to be the same as that used by Vauban, 180 toises. He used the same perpendiculars also; viz.: $\frac{1}{8}$ for a square, $\frac{1}{7}$ for a pentagon, and $\frac{1}{6}$ for a hexagon and all polygons of a greater number of sides.

With an exterior side of 180 toises and a perpendicular of 30 toises, Cormontaigne made the faces of the bastion 60 toises long, the flanks 20 toises, and the curtain 60 toises.

Having drawn the lines of defence through the extremity of the perpendicular, the lengths of the faces were laid off.

To obtain the direction of the flank, a right line is drawn

parallel to the perpendicular and 30 toises from it; an arc is described with the shoulder angle as a centre



and with a radius of twenty toises; the point where this arc cuts the line 30 toises from the perpendicular is the extremity of the curtain; the right line joining the extremity of the curtain with the shoulder angle is the flank (Fig. 46).

The curtain is parallel to the exterior side and 60 toises long.

103. Tenaille.—The tenaille is made with a curtain and wings. It is made seven toises wide, and is separated from the curtain and flanks of the main work by an interval of 5 toises.

104. Main Ditch.—The counterscarp is obtained by drawing right lines tangent to two arcs with radii of 14 and 15 toises respectively, described from the salients of the bastions and from the intersections of the scarp of the tenaille

curtain with the lines of defence, making the ditch one toise wider opposite the tenaille than at the salient.

The ditch is 22.50 feet deep.

105. Ravelin.—The ravelin is a redan with its faces each 60 toises long. The faces are directed so that their prolongations will intersect the bastion faces at points 15 toises from the shoulder angles. Its ditch is made 10 toises wide, and is of the same depth as that of the main ditch.

106. Ravelin Redoubt.—The ravelin is large enough to have a strong redoubt placed within it. This redoubt is a lunette in form, having its faces parallel to the faces of the ravelin and 15 toises from it. Its flanks are parallel to the perpendicular of the front, and are drawn as follows:

Produce the counterscarp of the main work until it intersects the perpendicular; from this point of intersection lay off a distance of 10 toises upon the line of counterscarp; this gives a point of the gorge of the redoubt; a line drawn through this point parallel to the perpendicular gives the inner line of terre-plein of the flank; a line drawn parallel to this line and 8 toises from it is the magistral of the flank. It is limited by its intersections with the face of the redoubt and the counterscarp of the main work prolonged.

107. Covered Way.—The covered way is made 5 toises wide. The crest of the ravelin covered way is a broken line, having a crochet and a traverse about half way between the traverses defilading the interiors of the places-of-arms.

108. Re-entering Place-of-Arms and its Redoubt.—Cormontaigne, while reducing the general width of the covered way of Vauban, increased the size of the re-entering place-of-arms, in which he placed a permanent redoubt.

The crest of the re-entering place-of-arms is determined by laying off, from the intersection of the counterscarps of the bastion and ravelin, distances of 27 toises upon these

counterscarps. With the extremities of these distances as centres, and with radii of 30 toises, arcs are described; the right lines joining the intersection of these arcs with their centres give the crest of the re-entering place-of-arms.

The magistral of the redoubt is obtained in a similar manner, substituting 20 toises for the distances laid off, and 18 toises for the lengths of the radii.

Traverses are used as in Vauban's trace to defilade the interior of the places-of-arms from slant reverse fires.

109. Interior Retrenchments. — Cormontaigne's trace includes a permanent retrenchment in the bastion.

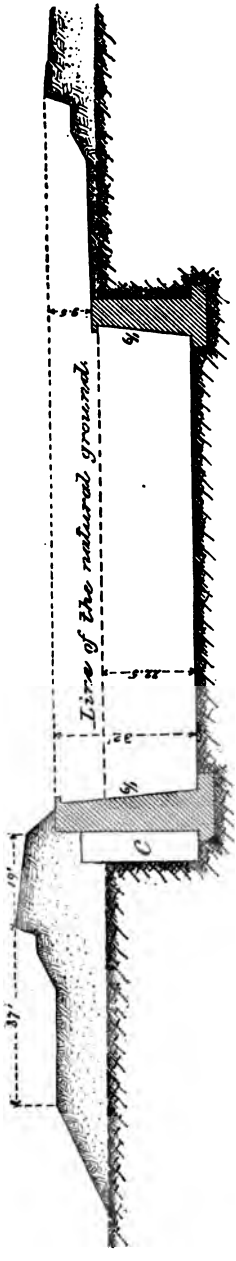
When the salient of the bastion was acute, he used ordinarily a cavalier with its faces parallel to those of the bastion. He completed the retrenchment by arranging a cut in the bastion face behind which a parapet was made, bringing a fire on the part of the bastion face where the breach would probably be made.

When the bastion was a large and roomy one, he placed the retrenchment upon a line joining the shoulders of the bastion, and used a bastion front for its form; or he placed it at the gorge of the bastion.

110. Profile.—In determining the profile of his work, Cormontaigne lays down the rule that the crest of the ravelin covered way should have a command of, *at least*, seven feet and a half.

In his trace, he makes the command of the crest of the salient place-of-arms at its salient eight feet and a half, and has the crest of the salient of the bastion covered way to command it by two feet, or makes the command of the crest at that point, ten feet and a half. The crest of the bastion covered way is inclined so as to have a fall of one foot to the re-entering place-of-arms. The command of the salient of the latter is the same as that of the salient of the

bastion covered way, and is given a similar inclination of a fall of one foot.



Cormontaigne's Method
Section on A.B. of Fig. 46.
Fig. 47.

The parapet of the main work is 19.0 feet thick (Fig. 47); the superior slope, $\frac{1}{8}$; the exterior slope, $\frac{1}{1}$; the berme, 18 inches wide; interior slope, $\frac{3}{1}$ (nearly); the banquette tread, 4.0 feet wide; banquette slope, $\frac{1}{2}$; the width of terre-plein, 37.0 feet; height of interior crest above the terre-plein, 8.0 feet. The top of the scarp wall is on a level (or nearly so) with the crest of the covered way opposite to it, and the wall is 32.0 feet high. [30.0 feet Fr.]

The face of the scarp is given a batter of $\frac{1}{8}$.

The interior crests of the bastion faces are slightly inclined, so as to have a fall of one foot from the salient to the shoulder angle. The flanks and the curtain are horizontal.

The profile of the outworks is the same as that of the main work, excepting in the tenaille and redoubt of the re-entering place-of-arms, the parapets of which are made 15.0 and 12.0 feet thick, respectively.

All faces exposed to enfilade

are made one foot higher at the salients than at their extremities.

The relief of the tenaille was determined in a similar way to that used in Vauban's method.

The ravelin is commanded by the main work and by its redoubt. The curtain of the main work commands the ravelin by 3.0 feet (nearly), and the redoubt commands it by 1.5 feet.

The scarp of the ravelin is 29.0 feet high, and of the ravelin redoubt, 16.0 feet.

The redoubt of the re-entering place-of-arms commands its covered way by 3.5 feet, and has a scarp 14.0 feet high.

The glacis planes contain the crests of the covered way and have slopes of one on twenty-four.

111. Remarks upon Cormontaigne's Method.—Cormontaigne's trace is simply a modification of that of Vauban, and possesses all the good qualities which characterize the latter's trace. Comparing his trace with that of Vauban, it is seen that:

1. The lengths of the faces of the bastions are greater, and the bastions are larger in Cormontaigne's trace;

2. The ravelin is larger, protects more of the scarp near the shoulder angles of the bastion, and allows room for the building of a strong permanent redoubt within it.

3. The re-entering place-of-arms is larger, admitting the use of a permanent redoubt within it, thus adding greatly to the strength of the covered way, and masking the scarp of the curtain from breaching batteries upon the glacis of the re-entering place-of-arms.

4. The masonry of the scarps is masked from direct fire of the enemy's artillery by being placed on a level with or below the crest of the covered way.

These are the principal and essential improvements made by Cormontaigne upon the first method of Vauban.

The **counterguard** was used by Vauban, and is given in Cormontaigne's trace. Cormontaigne used it only as an exceptional outwork, to strengthen a front that would otherwise have been, in his opinion, too weak if this outwork was omitted.

112. Improvements Made and Proposed in Cormontaigne's Method.—Engineers who succeeded Cormontaigne have made his trace a particular study, and have proposed improvements in it with the following objects in view, viz.:

1. To increase the command of the main work, considering that used by Cormontaigne to be too low;

2. To give a greater inclination to the superior slope, as that of $\frac{1}{9}$ used by him was too small to thoroughly flank the ditches;

3. To protect the masonry of the scarp of the bastion face exposed to fire coming through the ravelin ditch, from batteries on the glacis of the salient place-of-arms;

4. To protect the scarp of the face near the shoulder angle, and the shoulder angle, from fire through the ravelin redoubt ditch of batteries on the terre-plein of the ravelin salient;

5. To prevent the redoubt of the re-entering place-of-arms from being untenable upon the occupation of the ravelin salient by an enemy;

6. To add to the number of traverses upon the covered way;

7. To arrange the communications of the work so that they will be better protected from an enemy's fire, will be of no use to an enemy if he gains possession of them, and will be independent of each other;

8. To provide ample bomb-proof shelters for the defence.

An examination of the modern front, already described, shows what changes have been made to give these improvements to Cormontaigne's front. The cut in the ravelin face, the face cover in the ravelin ditch, the mask in the ravelin

redoubt ditch, the traverses on the covered way, and the bomb-proof shelters form the principal differences in the two traces.

As stated in a previous article, further improvements are demanded. The masonry must be protected from indirect as well as from direct fire, more traverses must be used upon the faces exposed to enfilade or oblique fire, covered defences and bomb-proof shelters provided, etc.

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CHAPTER IX.

POLYGONAL SYSTEM.

113. Rise of the Polygonal System.—Montalembert, who was born in 1713 and died in 1799, and Carnot, who was born in 1753 and died in 1823, were both distinguished writers upon "Fortification." Both of these distinguished men found fault with the bastion trace and the methods of construction employed by the French engineers of their day. Both of them proposed modifications in the bastion trace, and from their discussions and controversies the polygonal system, as it is now called, may be said to have been evolved. After the fall of Napoleon, the important defensive works on the frontiers of Germany were improved and strengthened. The German engineers accepted readily the views of those opposed to the prevailing French system, and applied the principles laid down by Montalembert to the improvement of existing works and in the construction of new ones. It is as well to state that the Germans claim to have traced the ideas of Montalembert back to their earlier German authors, and they consider these principles of Montalembert to have been identical with those advanced at an earlier period by German authorities.

Montalembert applied the name of "**polygonal**" to any trace in which all the angles are salient, or, if there were re-enterings, these latter were very slight. A work constructed on such a trace could not have its ditches flanked by the fire

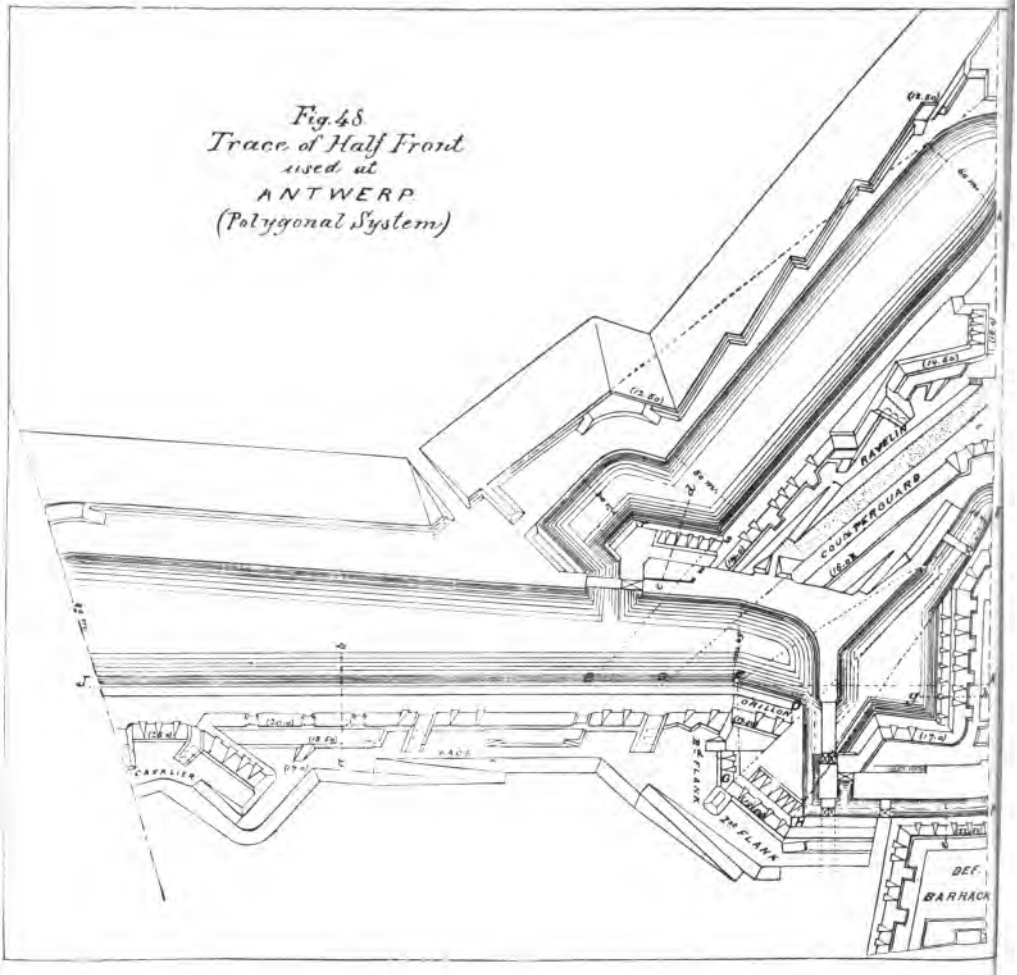


Fig. 48
Trace of Half Front
used at
ANTWERP
(Polygonal System)
RAVELIN
COUNTERGUARD
ORILLON
CAVALIER
FACE
1st FLANK
2nd FLANK
DEF.
BARRACK

of the work itself, but required other means for this purpose. The flanking of the ditches was effected by means of caponiers in the ditches, or by counterscarp galleries; that is, by works exterior to the work to be flanked.

The new fortifications constructed by the German engineers since 1815, are all upon the polygonal trace, and may be considered as the practical beginning and rise of the new system, although some few examples were in existence previous to that time.

114. Trace of the Main Work at Antwerp.—No better example can be taken to illustrate the principles of the polygonal system than that of the fortifications of Antwerp in Belgium.

The city of Antwerp having outgrown its defences, it was decided by the Belgian government, in 1859, to demolish the old fortifications and to construct new ones.

The new fortifications defending the city were planned by, and constructed under the direction of General Brialmont, a distinguished engineer officer of the Belgian service. These works are built according to the rules of the polygonal trace, and fully illustrate the principles of the polygonal system.

The city of Antwerp is situated on the right bank of the river Scheldt, and is enclosed by a continuous line of fortification which rests upon the river, above and below the city. This continuous line of fortification is composed of eleven fronts, the exterior sides of which vary in their lengths, the sum of these lengths being about nine miles.

Seven of the fronts are considered, in time of war, to be exposed to attack by "regular approaches," and are fortified with this object in view. The remaining four are supposed to be safe from this kind of attack, and are fortified simply with the view of making them safe from capture by assault.

The traces of the fronts exposed to regular attack are similar in character, and differ from each other only in minor

details and in the lengths of the parts. A description of any one of the seven will give a good idea of all of them.

115. Construction of Polygonal Trace.—The site at Antwerp is practically level, and admits the use of wet ditches, that are freely employed.

The general features of the trace employed in this continuous line of fortification are given in Figure 48.

The construction of this polygonal trace is as follows:

The length of the exterior side is taken, in this example, to be 1,000 metres, the average length used by General Brialmont in the fronts of the main work.

Through the middle point, **K**, of the exterior side, draw the perpendicular, **A P**. On this perpendicular, within the exterior side, lay off a distance, **K P**, of 65 metres; through this point, **P**, draw a right line parallel to the exterior side, laying off on it on each side of the perpendicular, a distance, **P H**, of 115 metres; the point **H** is the extremity of the curtain of the half front.

The flank is not continuous, but broken into two parts, called, respectively, **first** and **second** flanks. The first flank is given a direction such that its fire can sweep the ditch of the face of the caponier; and the second flank, that its fire can sweep the ground in rear of the caponier.

To obtain the magistrals of the flanks, it is necessary to determine the position of the salient of the caponier. This is determined by laying off the distance, **K E**, of 95 metres on the perpendicular outside of the exterior side; the point **E** is the salient of the magistral of the caponier.

Join the salient **E** with the end **H** of the curtain by a right line, and draw through **H** the line **G H** perpendicular to it; on this perpendicular lay off **H G**, equal to 31.5 metres; this line, **H G**, is the magistral of the **first** flank.

Through the extremity, **G**, of the first flank draw a line parallel to the perpendicular of the front, and lay off from **G**,

a distance of 11.0 metres; this is the magistral of the **second** flank.

Produce the magistral of the second flank until it intersects the exterior side; the intersection, **F**, is the extremity of the face, and **J F** is the magistral of the **face.** From the extremity of the face the parapet is broken inwards to give shelter to the flanks. This portion broken inwards is called an **orillon**, and its magistral is obtained as follows:

Lay off from **H**, the end of the curtain, on the line **H E**, a distance of 7.0 metres; through the extremity of this distance draw a line parallel to the perpendicular of the front; the extremity of the orillon is on this line. Through the extremity, **F**, of the face, draw a line making an angle of 30° with the exterior side, and produce it until it intersects the line just drawn parallel to the perpendicular; the intersection of these two lines is the extremity of the orillon, and the line **F O** is its magistral.

The end of the orillon is sustained by a profile wall, the direction of which is obtained by imposing the condition that the wall shall not interfere with the fire of the guns of the first flank. In the example, the profile wall starts from the end of the orillon, and runs parallel to the perpendicular of the front until it intersects a line, **G E**, drawn from a point of the first flank outside of the extreme embrasure to the salient of the caponier; it then follows the direction of this line, **E G**, and terminates on a line through the extremity of the second flank and parallel to the exterior side. By this construction it interferes with neither of the flanks.

The curtain is not made continuous throughout its whole length, but is broken into two parts, known as **half curtains,** by a construction called the **defensible barrack.** The half curtains are separated from the barrack by open roadways leading through cuts in the parapet and over bridges to the open ground, or low terre-plein, in rear of the caponier.

It will be seen that the trace of the main work of a front of this description consists of two **faces**, two **first** and two **second flanks**, two **half curtains** and a **defensible barrack.**

116. Caponier.—Since the form of the trace does not allow the ditch to be flanked by the fire of the work, an exterior work is employed for the purpose.

The ditch at the salients is 80.0 metres wide, and at the extremities of the faces 50.0 metres. The depth of water in the ditch is about ten feet.

The ditch is swept by the fire of a **caponier**, placed at the middle point of the exterior side.

The caponier has two **faces**, two **flanks**, and two **wings.** The triangular portion of the caponier bounded by the faces is commonly called the **head.**

The construction of the magistrals of the different parts of the caponier is as follows:

The magistrals of the faces coincide in projection with the lines, E H, etc., drawn from the salient of the caponier to the outer extremities of the curtains. They are limited in length by the intersections of the magistrals of the flanks.

The magistrals of the flanks are slightly inclined toward the perpendicular of the front, the exterior angles made by them with the exterior side being about 100°.

The caponier has an inner court, the sides of which are parallel to the magistrals of the flanks. This court is 10.0 metres wide at its outer end, and 16.0 metres wide where it is intersected by the exterior side; it is 70.0 metres long, the outer end being 50.0, and the inner end being 20.0 metres from the exterior side.

Constructing this court, the magistrals of the flanks are obtained by drawing lines parallel to the sides of the court and 30.0 metres from them; these lines will be the magistrals of the flanks. They are limited in their lengths by their intersections with the magistrals of the faces and wings.

The magistrals of the wings are obtained by drawing right lines joining the middle point of the inner end of the court with the ends of the orillons; the projections of the magistrals lie on these lines. The extremities of the wings are drawn back, and terminated by traverses.

To obtain the magistral of the portion of the wing drawn back, draw a line parallel to **H E** and 6.0 metres from it; the magistral of the part drawn back will be on this line.

The traverse terminating the wing is placed so that its side shall be parallel to the perpendicular of the front; the outer extremity being on the line **E H**, and the inner being at the intersection of a line drawn through the middle of the second flank with a line drawn through the extremity, **F**, of the face and perpendicular to the line **E H**.

The flanks of the caponier are arranged with two tiers of fire; the lower tier is casemated, the upper one, an open battery. Traverses are used to defilade the terre-plein of the open battery.

The faces of the caponier are swept by the fire of the first flanks. Its flanks are swept by the fire of the wings. The terre-plein in rear of the caponier is separated from the half curtains and the defensible barrack by a wet ditch, 8.0 metres wide, and is swept by the fire of the second flanks. Drawbridges afford communication across the ditch between the low terre-plein in rear of the caponier, and the open roadways through the curtain of the main work.

117. Defensible Barrack.—The defensible barrack, as before stated, separates the half curtains from each other. It is quadrilateral in form, the head being on a line with the magistrals of the half curtains. Its flanks, or sides, make with the head an angle of 100° measured on the interior, and are 75.0 metres long. The gorge is closed by a defensive arrangement, making the barrack a **keep** for the front.

The head is masked from an enemy's fire by the caponier

and the orillons of the main work. To construct the magistral of the head, a line is drawn through the interior crest of the extremity of the orillon and the inner end of the traverse terminating the wing of the caponier; this line is produced until it intersects the magistral of the curtain; a distance of 8.0 metres is laid off on the curtain from this point toward the perpendicular; this gives one of the extremities of the head of the barrack; the other extremity is determined in the same way; and the right line joining these points is the magistral of the head of the barrack.

The distance of 8.0 metres is to give the necessary width for the open roadway adjacent to the barrack, and to keep this roadway covered by the caponier and orillon from the direct fire of an enemy.

118. Outworks.—Exclusive of the caponier, the outworks of this particular front consist of a **counterguard**, a **ravelin**, two **low batteries**, and a **covered way**.

The magistral of the counterguard consists of two faces, the directions of which are obtained by laying off **K C** on the perpendicular equal to 165 metres, and **K D** on the exterior side equal to 175 metres; the line joining **D** and **C** is the magistral of the face of the counterguard.

The magistral of the ravelin is obtained by laying off **K A** equal to 270 metres and **K B** equal to 225 metres; the line, **A B**, joining **A** and **B**, is the magistral of the face of the ravelin.

The magistral of the low battery is obtained by laying off on the line **A B**, from its point of intersection with the counterscarp of the main ditch, a distance of 45.0 metres; through this point thus determined a line, **S T**, is drawn, making the angle **A S T** equal to 120°; on this line a distance of 50.0 metres is laid off; the line **S T** is the magistral of the low battery.

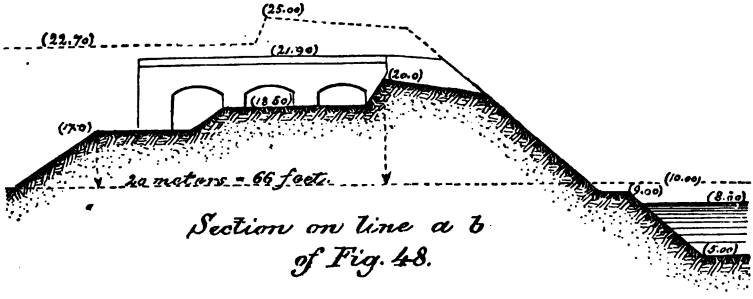
The covered way of the main work is 20.0 metres wide,

and its crest is parallel to the counterscarp of the main ditch.

The ravelin covered way is from 8.0 to 14.0 metres wide; its crest is a crémaillère line, the short branches being perpendicular to the perpendicular of the front, and 6.0 metres long.

119. Profile.—The profile of the face of the main work is given in Figure 49. The references are in metres.

Fig. 49.



The thickness of parapet is 8.0 metres; the superior slope is $\frac{1}{8}$; the exterior slope, $\frac{3}{4}$; the width of berme, 5.0 metres; the interior slope is left at the natural slope of the earth; the width of terre-plein is 20.0 metres; the rampart slope, $\frac{2}{3}$. The terre-plein is composed of two levels; the upper one is one metre and a half below the interior crest and arranged for artillery; the lower one is 3.0 metres below the interior crest, and is 10.0 metres wide. The slope joining the two levels is that of the natural slope of the earth.

The guns are mounted for barbette fire, excepting a few shallow embrasures for an oblique flanking fire. They are protected from oblique fire by bonnettes on the parapet and traverses along the terre-plein.

Two of the fronts might be exposed to an enfilade fire,

and their salients are provided with cavaliers to defilade their faces. These cavaliers (Fig. 48) consist of two faces and two flanks, each 45.0 metres long. The faces are parallel to the exterior sides, and the flanks make with the faces an angle of 140° measured on the interior.

The cavalier has a command of 5.0 metres over the face of the main work, and the latter has a command of 10.0 metres over the plane of site.

The face commands the flanks and the curtains by a half metre, and the orillon by two metres and a half.

120. Remarks upon the Main Work.—The faces are given such directions and command as to obtain a strong artillery fire over the ground in their front, and to be safe from enfilade fire. Where there is a probability of an enfilade fire, a cavalier is used to defilade the faces.

The scarps of the faces are not revetted, the wet ditch being considered a sufficient obstacle against assault.

The scarps of the half curtains and the defensible barrack not being exposed to the enemy's fire are revetted. The scarp from the orillon to the curtain is also revetted for the same reason.

The first flank is arranged with two tiers of fire to sweep the ditch of the head of the caponier. The lower tier of fire consists of six guns in Haxo casemates; the upper tier is an open battery of four guns. The floor of the casemates is about five feet above the level of the water.

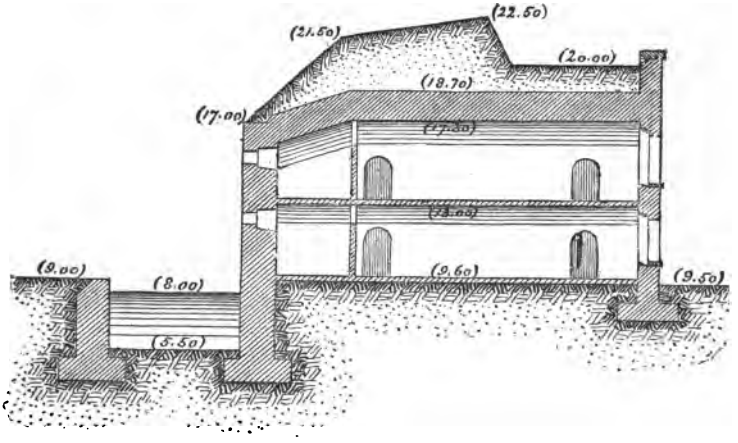
The second flank is also arranged with two tiers of fire; an open battery of two guns on the terre-plein; the other, in casemates. The casemates of this flank not being exposed to an enemy's fire, the front wall of the casemates is not masked with earth, as in the case of the first flank. The floor of the casemates is made 8.0 feet higher in the second flank than in the first, so as not to have an interference of fire of the two flanks, and to allow the second flank to fire over

the masks placed in front of the casemates of the first flank.

The orillon, besides giving cover to the flanks, shelters the space in rear of it from the enemy's fire. This space forms a place of assembly for troops. Bomb-proofs are built under the orillon as shelters for the troops guarding the berme.

The rampart is high enough to allow bomb-proof shelters to be built all along the face, a thing proposed by General Brialmont in his modified trace.

Fig. 50.



Section on line e f of Fig. 48.

121. Remarks upon the Defensible Barrack.—The head of the barrack, as it is not exposed to fire, is revetted, and the top of the wall is at the same level with the crests of the wings of the caponier, or has a reference of (17.0) mètres. The profile made by a section perpendicular to the head is given in Figure 50. It is arranged with two tiers of casemates and an open battery on top.

From the great command given to the crest of the open

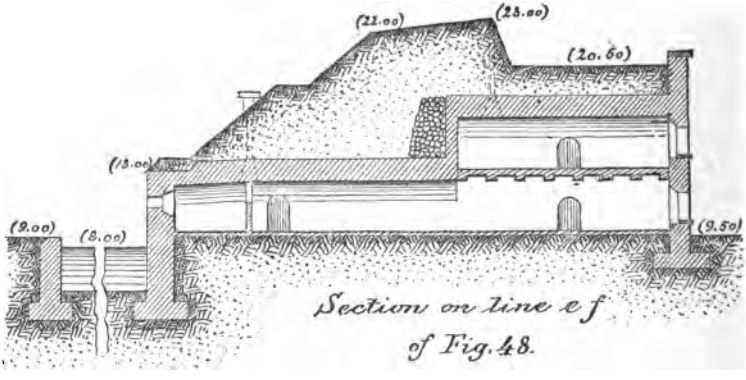
battery, the fire of the head of the barrack can be brought to bear on the ground in front of the ravelin. The fire of the flank's sweeps the ramparts of the faces of the main work, and takes in reverse the besiegers' works opposite the ravelins of the adjacent fronts.

The gorge being closed, the barrack forms a keep for the front, and a guard for the main entrances of the work.

The casemates for quarters are sufficient to accommodate a garrison of 2,000 men.

In case of a siege, it may become necessary to fill the front portions of the casemates of the upper tier. In anticipation of this, General Brialmont has proposed a change in the construction, as shown in Figure 51.

Fig. 51.



In this modification, the scarp of the head is placed 4.0 metres below the crest of the wing of the caponier.

122. Remarks upon the Caponier.—The caponier has two tiers of fire; sixteen gun casemates in each flank, and six guns in open battery over the casemates. The front wall of the casemates is protected by earthen masks. The floor of the casemates is one metre above the level of the water.

The open court affords communication between the main

work and the counter-guard. It is also useful to ventilate the casemates on each side of it. The casemates are deep enough to serve as quarters for the gunners. In action, the rear openings are to be blocked up, as shown in Figure 52, which represents the profile of one flank of the caponier.

Chimneys with fire-places are constructed in the casemates to assist in ventilating them, in removing the smoke of the guns, and to make them comfortable in cold and damp weather.

In time of siege, it is not expected to be necessary to use all the guns in the casemates at once, excepting possibly at the termination of it. Every other casemate will have its gun-port closed and the casemate used for the gunners, the guns in the closed casemates being held in reserve to replace any gun disabled or dismounted by the enemy's fire. In peace, all the gun-ports are kept open for ventilation. The open battery above the casemates is commanded by the faces of the main work by three metres.

The wings of the caponier are intended to cover the masonry of the defensible barrack, but they are further utilized to obtain a fire upon the terre-plein of the counter-guard. The reference of the wings is (17.0) metres. The head of the caponier is revetted, and, from its position, it will be a difficult task for the besieger to counter-batter and breach it. It is assumed that he will be obliged to attack it by mining; and, to add to his difficulties, the head is formed of three tiers of reversed arches filled with earth.

Each of the caponiers of the fronts at Antwerp is provided with two powder magazines, two shell rooms, one small laboratory, one kitchen, an officer's set of quarters, store-rooms for supplies, and privies.

The caponier, in the polygonal trace, is the most important of all the outworks. General Brialmont lays down the following rules to be observed for this work:

1. It must be safe against assault.

2. It must be placed so as to thoroughly flank the main ditch, and command the principal entrances of the main work.

3. It must have its guns in readiness to repel at all times an open assault.

123. Remarks upon the Outworks.—The **counterguard** is separated from the caponier by a wet ditch, 18.0 metres wide. Its counterscarp is revetted from the head of the ditch to the points of its intersection with lines drawn from the salient E of the caponier to the extremities of the faces, F, etc., of the main work.

Its interior crest has a reference of (16.0) metres, and is parallel to the magistral, excepting at the salient, where it is rounded and arranged for a battery of siege howitzers to fire in the direction of its capital. The exterior slope extends to the bottom of the dry ditch that separates the counterguard from the ravelin. It is intended that the foot of this slope shall be provided with a detached wall, or with a palisade, as an obstacle.

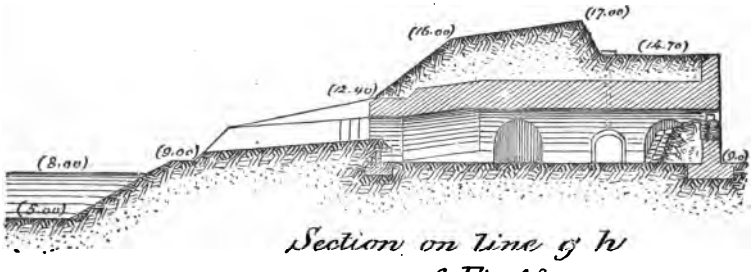
The object of the counterguard is to cover the masonry of the head of the caponier, of the flanks, and of the half curtains, and the communications of the main work across the ditch, from an enemy's fire. It also fulfils the part of the ravelin redoubt of the bastion trace in strengthening the ravelin.

The **ravelin** is separated from the counterguard by a dry ditch 15.0 metres wide, and from its covered way by a wet ditch 60 metres wide at the salient and 50 metres at the low batteries. Being exposed to enfilade fire, its interior crest is not made parallel to the magistral, but is broken, as shown in Figure 48, in accordance with the principle of "independence of parapets."

Two ordinary traverses and a casemated traverse are built upon each face, and a traverse containing a casemated battery is placed in the salient. This battery in the salient is ar-

ranged to fire in a direction parallel to the exterior side, and contains four gun casemates on each side. It is called a **reverse battery,** since it would see in reverse the besiegers' trenches if they were advanced upon the main work before obtaining possession of the ravelins.

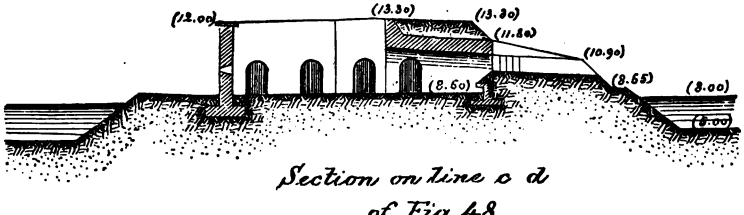
Fig. 52.



Section on line g h of Fig. 48.

The **low batteries** are casemates (Fig. 53), the front walls of which are protected as in Haxo casemates. There are six casemates in each battery, provided with magazines and guard-rooms. The floor is a half metre above the level of the water.

Fig. 53.



Section on line c d of Fig. 48

The top of the earth covering is placed as low as possible to prevent interference with the fire of the main work.

The battery is enclosed in rear by a loop-holed wall to

make it secure against assault, and to protect the men in the battery from the fire of the caponier.

The object of the low battery is to flank the ravelin ditch and to act the part of the redoubt of the re-entering place-of-arms in the bastion trace. It is separated from the covered way by a wet ditch 40.0 metres wide.

The **covered way** is wide and commodious. Traverses are generally omitted, as they obstruct the movements of troops, and interfere with the fire of the defence. A traverse is used in the re-entering place-of-arms to shelter the communications along the covered way of the face of the work.

124. Communications.—The communications are free, ample, well arranged, and independent of each other.

Two main roadways lead from the main work, through arched gateways under the half curtains, and across draw-bridges and causeways to the ends of the wings of the caponier. Then by draw-bridges and causeways across the main ditch to the counterscarp and along the covered way of the ditch. These causeways are separated from the scarp of the flanks by wet ditches 8.0 metres wide.

These main roads following the counterscarp, cross the ravelin ditch by bridges in rear of the low batteries, and lead to the front by cuts in the glacis. These roads are nowhere less than 8.0 metres wide.

Besides these main roadways, there are the two open roadways on each side of the defensible barrack. They lead by bridges to the ground in rear of the caponier, and then by posterns into the inner court and into the casemates of the flanks.

Ramps and stairs connect the different levels of the main work and the outworks.

Generally, the roads are level and direct, well protected from an enemy's fire, and convenient for the use of troops.

125. Comparison between the Bastion and Polygonal

Systems.—General Brialmont has applied the principles of the polygonal system to the construction of the fortifications of Antwerp, but has constructed these works upon a much larger scale than any used by his predecessors. These works have had great weight in determining the profiles and traces of recent works built in Europe, and have therefore made the front of Antwerp especially worthy of study.

The advantages of one trace over the other may be seen by comparing this front of Antwerp with the "modern front" or bastion trace, and an opinion of the merits of the two systems may be formed. In both fronts, ample bomb-proof shelters, strong interior retrenchments, and good communications are requisites, and are to be provided. These may, therefore, be neglected in making the comparison.

Examining the bastion trace, it is seen that:

1. A correlation exists between the lengths of the exterior side and curtain, and the relief of the work. Without such reciprocal relation, the flanking arrangements would be defective.

2. A diminished angle of considerable size is necessary to give flanks of sufficient length to furnish the requisite amount of flanking fire. The greater this angle is made, the more will the amount of interior space enclosed by the work be decreased, and the more will be the increase in length of interior crest for the same length of exterior side.

3. The faces of the bastion have such directions as to expose them more or less to enfilade.

4. The flanks are not only exposed to enfilade, but also to reverse fire.

Examining the polygonal trace, it is seen that:

1. No correlation exists between the different parts of the work.

2. The interior space enclosed by the main work is greater for this trace than for the bastion.

3. The faces are less liable to be exposed to enfilade fire.

4. The flanks are less exposed to reverse fire.

It is also seen that a stronger artillery fire can be had upon the ground in front, and more artillery can be used on the faces of the main work in this trace than in that of the bastion.

Also, an enemy attacking a front fortified by the polygonal system will be obliged to have a greater extent of trenchwork than would be required were it fortified upon the bastion trace.

In both systems, whether the obstacle to assault be a wet ditch, or a scarp wall, it is required that the obstacle be strongly defended. Flank defence is considered to be the most effective for this purpose, and to require fewer men and guns.

In the bastion trace, this flank defence is obtained from the rampart or the parapet of the work itself; in the polygonal, by using the fire of a construction exterior to the main work. This exterior construction is usually a casemated caponier with two, and sometimes three, tiers of fire, the casemates being of masonry.

The ease with which masonry can be destroyed by the fire of heavy guns has been one of the principal objections to the polygonal trace. For, it is evident that a besieger left unmolested in the ditch would soon bridge it if wet, or throw down the wall if this be the obstacle, and get possession of the parapet.

Where there is danger of the flank defences being disabled before effective use can be made of them, it is plain that they would form a defective arrangement in the trace, and would constitute an objection to the system.

The inconvenience caused by smoke in the casemates has for a long time been considered a serious objection to their use. Later constructions have shown that this is no longer so serious a matter, and that the smoke can be easily removed

from the casemates. Experience has shown, however, that caponiers with more than two tiers of fire are easily disabled and should not be used.

The merits of the two traces are peculiarly noticeable when the traces are to be applied to the actual ground. The bastion trace can be applied less readily than the polygonal to sites of an irregular nature.

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CHAPTER X.

METHOD OF FORTIFYING A PLACE.

126. Origin of Permanent Fortifications.—Fortifications have been used by man from the earliest times. As a place, town, or city grew in value, or became of importance, fortifications were built by the inhabitants to secure the safety of their lives and property threatened by hostile neighbors. These fortifications became permanent in kind, and were first erected for local defence alone. Afterward, as governments became more consolidated and stronger, wars more national in their character took the place of the forays and invasions of the earlier periods. The government assumed charge of the permanent fortifications of a country, and gave to the works other functions besides the single one of local defence. Attention was paid to securing those points of a country that were liable to be attacked in time of war, those points which, if held, would check an enemy's advance; those points which, if fortified, would assist the operations of an army sent forward by the government to repel an invasion, etc. Besides the defence of the place, other objects that were national in their character were to be attained by the works. National considerations therefore increased the local importance of these works, and permanent works as they now exist may be considered to date from that period when national, as well as local defence, was the object sought by their construction.

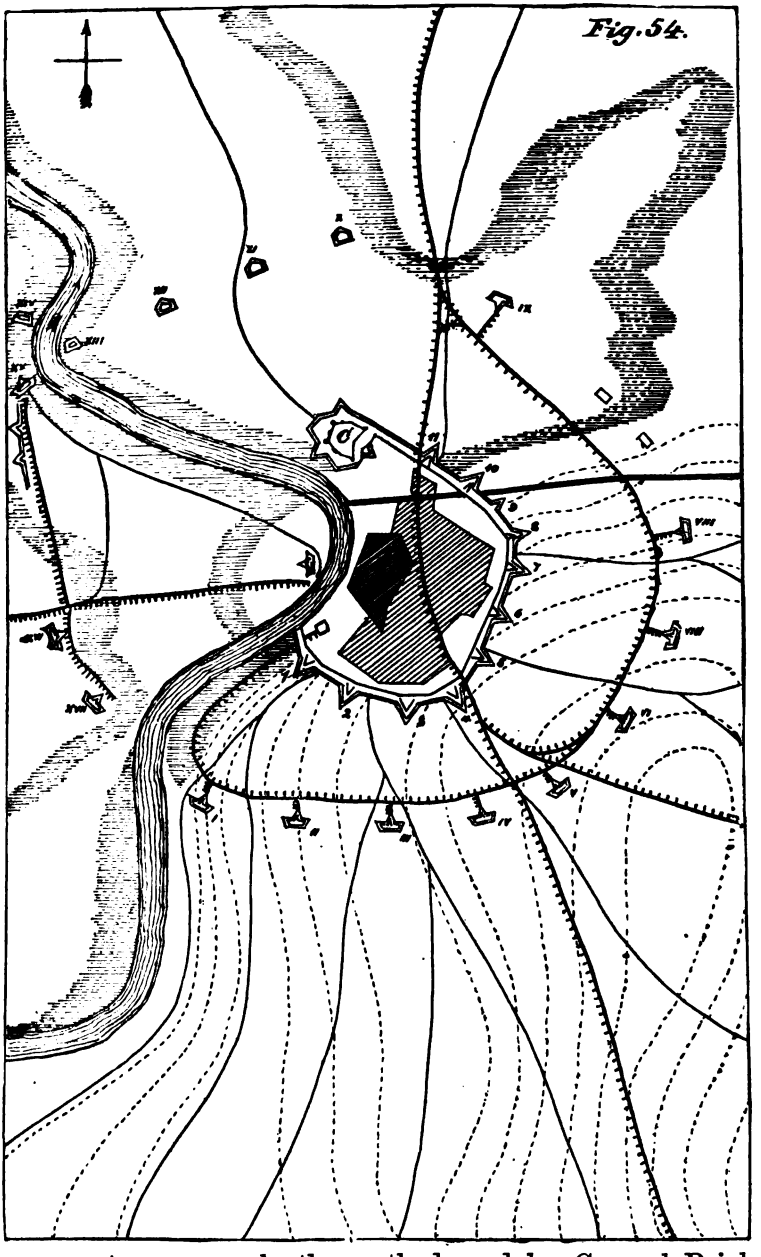
127. Places to be Fortified.—Without discussing the question of fortifying frontiers, coast-lines, or a country in general, it is a fact that there are always points in a country that an enemy will at once attempt to seize upon war being declared. These points are usually political centres, or points of manufacturing or commercial value. A wise government, anticipating future wars, fortifies such points, either to have them form dépots of supplies for its armies, or to have them as points of support and shelter for its armies operating to repel an invasion. In either case, they should be made safe against a sudden attack, and strong enough to enable the garrisons to repulse the attack of a superior force without the aid of other troops. If the place is also to be a shelter and a point of support for an army, it should be provided, in addition to the works manned by the garrison, with an intrenched camp in which the troops may be recruited and rested.

The capital of a country is a political centre of great importance to its own state, and, in case of an invasion, is apt to be the point that an enemy desires to seize. Prudence would indicate that a point of this kind should be fortified, or the lines of operation leading to it be blocked by fortified places, so as to make it safe against sudden invasion.

Napoleon said, "It is the greatest of all absurdities to leave so important a point [the capital] destitute of immediate defence."

128. Method Employed to Fortify a Place.—The method used at the present time to fortify a place of great importance is to enclose the place by a continuous line of fortification, and, exterior to this line, to construct a line of detached works sufficiently far from the inner line to allow room for an intrenched camp, and far enough from it to keep an enemy from shelling the fortified place.

An example of the method is given in Figure 54, which



represents very nearly the method used by General Brialmont to fortify Antwerp

General Brialmont enclosed the city of Antwerp by a continuous line of fortification consisting of eleven fronts, numbered in the Figure as 1, 2, 3, etc. The traces of the fronts are all constructed in accordance with the principles of the polygonal system. The seven fronts from 1 to 7, inclusive, are constructed as described in the last chapter. The remaining four fronts are more simple, having no outworks excepting the caponier to flank the ditches, as these fronts are not exposed to attack by regular approaches. It will be observed that the salients of the enclosing polygon are so obtuse that the prolongations of the faces intersect the adjacent ravelins. It is to be remembered that General Brialmont had to consider in laying out his lines of fortification other questions besides the simple one of defence. The nature of the ground, the situations of villages, the existence of beautiful villas and residences, etc., all had their influence in the selection of these lines, and the questions of economy and good policy caused changes to be more or less made in his plans.

As previously stated, the continuous line of fortification, or main work, terminated on the banks of the river above and below Antwerp. The main work terminated on the north side in a large work called the **north citadel**.

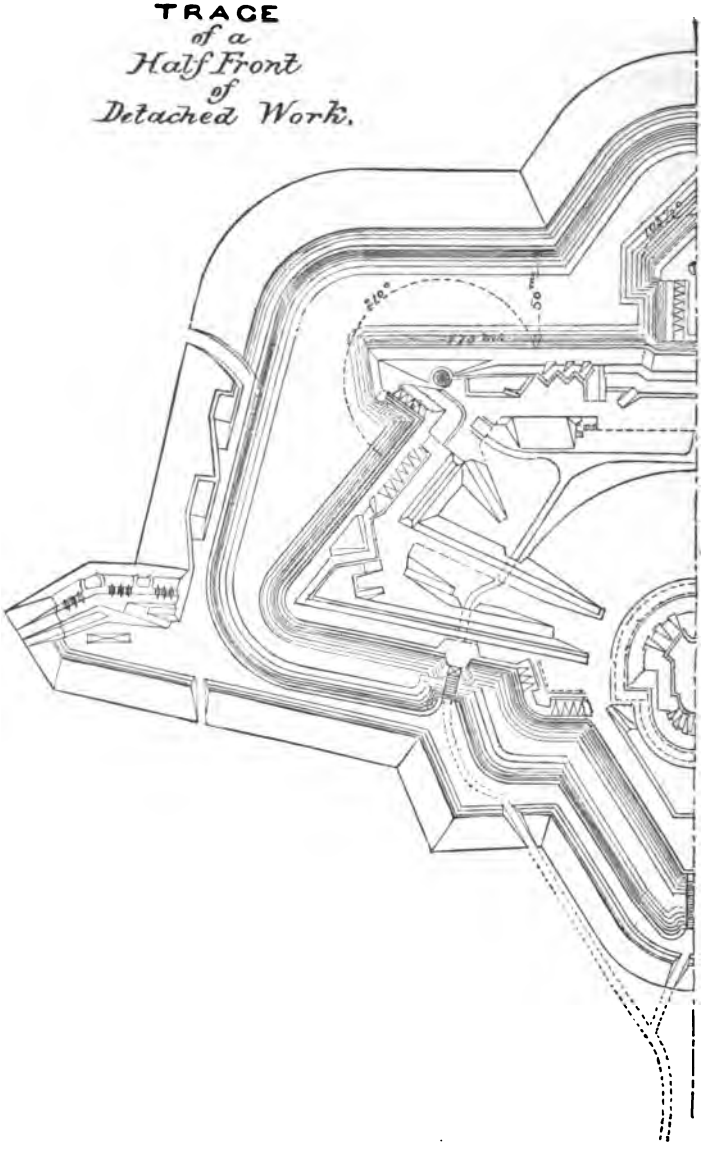
This citadel is composed of seven fronts, on an irregular polygon of seven sides. Five of these fronts are flanked by caponiers; the remaining two, being on exterior sides that make a re-entering angle, are arranged to flank each other. The latter two fronts face the interior of the main work.

The object of the citadel is that of an interior work into which the garrison can take refuge when the main work is no longer tenable. Its fronts are arranged to sweep the river front of the city, and to sweep the reach of the river in front of the citadel.

General Brialmont did not think it necessary to enclose the left bank of the river by a continuous line, since the ground

Fig. 55.

TRACE
of a
Half Front
of
Detached Work.



upon that side of the river near the city could be inundated at will.

The **detached works** were placed about a mile and a quarter from each other (I, II, III, IV, etc., Fig. 54), and from two to three miles in front of the main work. These works are large and strong ones, constructed according to the polygonal system.

An outline of the trace of half of one of these detached works is given in Figure 55, and is a type of them all.

The front toward the enemy is called the **principal** front; the sides are termed **lateral** fronts; and the rear is called the **gorge front.**

The principal front is 350 metres long, with a wet ditch 50 metres wide, flanked by a caponier at the middle of the front. The caponier is armed with 14 guns, 7 on each flank, and is separated from the scarp of the front by an interval of 8.0 metres. The head of the caponier is made to extend beyond its flanks, so as to mask the embrasures from the enemy's fire.

The lateral fronts are made about 150 metres long. The magistral of the lateral front makes with the principal front an angle of 150°. This line being exposed to enfilade, the interior crest is not held parallel to it, but broken into a crotchet, as shown in the Figure. An orillon is formed at the junction of the lateral front with the principal, and a casemated battery placed behind it to flank the ditch of the lateral front. The branch of the crotchet near the end of this front flanks the ditch adjacent to the orillon.

The gorge front is composed of two branches that make an angle of 150° with each other, the salient being to the rear.

Between the branches of this front there is placed a defensive casemated keep that will hold 200 men. This keep is covered in front by a glacis, and in rear by a redan.

In the re-entering made by the redan with the faces of the gorge front, casemated batteries of seven guns are built to flank the ditches of the gorge front and the redan.

Bomb-proof barracks capable of accommodating 1,200 men are provided, as well as powder magazines, store-rooms, etc.

The armament is 120 guns and 15 mortars.

The covered way in front of the detached work is reduced in width to a simple pathway for the use of sentinels. The covered way of the sides is provided on the flanks with barbettes for field guns, as shown in the Figure. The covered way of the gorge front is commodious and suitable for the movements of troops.

General Brialmont proposes that iron turrets should be placed on the extremities of the principal front and on the head of its caponier. He also suggests one upon the head of the keep, and claims that one gun in a turret is equal in efficiency to three in casemates.

A belt railroad runs in rear of the detached works (Fig. 54), with branches leading from it to the different forts, thus affording easy and rapid communication between the fortified city and the detached works.

129. Remarks upon the Method of Fortifying a Place.—It is well known that the character and extent of the permanent works built to defend a place have generally been more or less governed by financial considerations. Rarely are the works built according to the complete plans of the military engineer, on account of the expense to be incurred. In all probability, this will frequently be the case in the future as it has been in the past.

On the score of economy, and also for other good reasons, it is highly probable that the continuous work, entirely enclosing a city or large place, will be omitted in the future. If constructed, it will be the last thing done and not the first.

The first thing to be done in fortifying a place will be to surround the site by a line of detached works, and to construct a good road, or railroad, in rear of them, as shown in the defences of Antwerp.

This line of detached works must be located far enough away from the site to make the place safe from any bombardment of the enemy.

The long range of modern artillery will require for this purpose that this line be placed from four to five miles away from the site to be fortified. This long range also allows the detached works to be placed farther apart than formerly, although the distances apart will be largely dependent upon the nature of the ground.

These detached works will be made strong enough to require them to be taken by siege operations, and large enough to accommodate the garrisons who are to defend them. The particular size of a detached work will depend upon its relative importance to the rest of the position. General Brialmont says: "A garrison of a large fort of 1,500 or 1,800 men commanded by a colonel will have usually a better spirit and be more ably handled, than a garrison of a small fort of 300 or 400 men commanded by a captain or a major." Holding this view, he advocates large works for the outer line. The French, in their recent constructions, have accepted this view of General Brialmont. The Germans are satisfied with smaller works: works requiring a garrison of about 500 men, and having an armament of 20 guns.

The system used for the trace may be that of the bastion, or the polygonal, or even a combination of the two. The natural features of the ground and the predilections of the engineer will largely influence the selection of the trace. The polygonal system is at present the favorite one.

In planning a detached work, the engineer will have to consider the following, viz.:

1. The general form of trace.
2. The construction of a keep.
3. The arrangement of the parapets and the disposition of its armament.

4. The flanking of the ditches.

Generally, the form of trace preferred is that of a lunette; the angle of the salient being from 130° to 145° to protect the faces from enfilade. General Brialmont prefers to the lunette the single straight front, as shown in Figure 55.

In recent constructions, the French and Germans have omitted the keeps, considering their usefulness not equal to their cost. A keep uses up a part of the interior space necessary for the garrison, and has the defect of intercepting the shells flying over the parapet, and being liable on this account to become disabled at the same time with the work.

General Brialmont, with others, contends for their retention, and says: "A keep is an indispensable work for every important fort that is detached, or occupies a salient position." Another authority says: "To dispense with the keep would be as faulty as to fight a battle without a reserve."

Instead of placing the keep in the gorge, it is recommended by some authorities to push it further forward into the work, in this way giving more protection to it.

General Brialmont prefers it in the gorge, so that it may command the ground on the flanks and in rear of the work. He also considers this work as particularly useful in guarding the fort from capture by sudden assault, and very useful in supporting the attempts to recapture the work after it is in the possession of the enemy.

The value of a keep was shown in the late war between Turkey and Russia. The Russians obtained possession of a detached work, but the Turks holding the keep forced the Russian troops to seek shelter outside of the parapets of the work, and continued to hold the keep until the surrender of other works made further resistance on their part useless.

The arrangement of the parapets and the distribution of the armament form a difficult problem to be solved by the military engineer. The parapets are to be arranged and

guns placed so as to best resist both an assault by overwhelming numbers, and a strong converging fire of many siege guns. A fort is weakest when an enemy first reaches it, and the more vigorous and prompt the attack, the greater are the chances of its falling. To anticipate such attacks, and to prepare the work to resist them, require a judicious arrangement of the parapets and a good distribution of the artillery throughout the work.

The trials made with iron plate to protect the gun-ports of casemates have not proved satisfactory, and the result is the use of casemate fire only in those positions where the embrasure is not exposed to either direct or indirect fire.

Casemate fire to the front has therefore been in a great measure abandoned in the works recently built. The fire to the front is over the parapet, being either barbette or indirect fire. The barbette guns are mounted on high carriages, and are brought into use to repel assaults. The guns for indirect fire are hidden by the parapet, and some of them are in batteries in rear of the rampart.

Iron turrets and the chilled cast-iron gun-port shield, known as Gruson's, are being used to get the barbette and direct fire of heavy guns in some of the new works.

Guns upon depressing carriages, that is, on a gun-carriage that may be lowered so as to place the gun below the parapet, and raised so as to allow of its firing over the parapet, are also employed. The gun-carriage of this description which is best known is the Moncrieff counterweight carriage. It is, however, considered by many as too liable to be injured, and too expensive to be generally adopted. Count Geldern of the Austrian engineers proposes the use of lifting platforms that work in circular pits.

General Brialmont says: "A great step will have been made when some person has devised a disappearing gun-carriage of simple construction and of moderate cost, that

will allow a gun to fire over a parapet about ten feet high."

Interior batteries, to be armed with heavy guns, are used in some of the modern forts. These batteries are placed about 60 yards in rear of the parapet of the fort and slightly below it. The parapet in front of the battery is arranged for the use of small-arms and field-guns, and acts as a screen for the battery behind it. The parapet of the battery, in its turn, acts as a parados for the parapet of the gorge.

The ditches are flanked by caponiers, excepting when the bastion trace is used. This trace is sometimes used for the gorge front, while the others are constructed on the polygonal system.

The older detached works, lunettes in form, were flanked by caponiers placed at the shoulder angles. Subsequent events proved this position to be faulty, and the faces are flanked in the more recent works of this form by a caponier at the salient. The flanks are swept by the fire of batteries placed near the shoulder angles, as in the detached work shown in Figure 55.

The weapons of the future to flank the ditches will be probably machine-guns, such as the Gatlin, the Hotchkiss, etc. Guns of this kind require fewer men and less space for their service.

130. Amelioration of Fortifications.—Works may already exist at or around a place that is to be fortified, but, as at Antwerp, inadequate to the purpose. The engineer will, in such a case, be frequently required to utilize the existing works in planning the new ones. The modification and reconstruction of existing works to make them better suited to defend a place is termed the "amelioration" of fortifications.

The old works constructed according to the methods of Vauban were particularly arranged for making an obstinate defence at the close range of musketry. The critical period of

the defence was considered to be from the time the enemy began to establish his batteries on the glacis until the main ditch was crossed by him.

Outworks were built expressly to prolong the defence and make it obstinate at this period. These outworks, as has been seen, mask more or less the fire of the main work, and when breaches are made in them, expose more or less the scarps of the main work. With the increased range of artillery and musketry, outworks as then constructed are now sources of weakness rather than of strength. Modifications became necessary, and the amelioration of the work resulted.

As an example, it will be remembered that the ravelin in Vauban's First Method gives but little protection to the scarp of the main work excepting for the curtain. Also, that its salient is but slightly in advance of the salients of the adjacent bastions. To remove the defects flowing from this size of the ravelin and still retain it, another work was added to the trace. Its usual form was a lunette, and it was placed in front of the ravelin near the foot of the glacis.

This work was near enough to the main work to be under the fire of musketry of the works in its rear, and was connected with the salient place-of-arms by a covered communication. A work of this kind is called an **advanced work.**

In time, it became necessary to use other works in advance of these, to occupy points which if in possession of the enemy would give him certain advantages in his attack. When these works are too far in advance to be defended by the musket fire of the main work and its outworks, and have to be provided with their own flanking arrangements, they are termed **detached** works.

Detached works are of old date, but their use has become a matter of vital necessity in the present era of fortification. By their use a more active defence is allowed, and the besieger is kept at a distance such that he is not able to bom-

bard the place until he gains possession of the line of detached works.

Analogous to the three kinds of interior works, viz.: the interior retrenchment, the cavalier, and the citadel, there are three kinds of exterior works, viz.: the outworks, the advanced works, and the detached works.

131. Provisional Fortifications.—When war is imminent it becomes necessary to strengthen certain points of a country, to prevent their seizure by an enemy upon the war breaking out. When these points have been allowed to remain unprotected, as is frequently the case, it becomes important to construct the fortifications in a hasty manner, or to complete them, if only partially built. The works thus constructed are stronger than those known as field works, and weaker than those classed as permanent fortifications. They are a compromise between the two kinds, and are designated as **provisional** fortifications. Some military writers speak of them as **semi-permanent** works.

The distinguishing difference between provisional and permanent fortification is in the absence of masonry constructions in the former, there not being time to build masonry structures and complete them. Heavy timbers, railroad iron, and iron girders are used in place of the masonry.

The shortness of time allowed to the constructions of these works will prevent the use of ditches as deep and profiles as strong as are used in permanent works. The same rules will, however, apply to their construction in providing thorough flanking arrangements, ample bomb-proof shelters, etc.

In the late civil war in the United States, there were no fortifications defending the city of Washington, except a small work below the city upon the banks of the Potomac, when the war began. Immediately after hostilities began, efforts were directed to surround the city by a line of detached works.

The works were built, at first, with the profiles and the revetments of temporary works. As the war went on, these works were gradually strengthened and enlarged, until at the close of the war, the dimensions of the profiles had been so much increased as to remove the works from the class of field fortifications, and to give them the character of semi-permanent works. The utility of these works is recorded in the history of that war.

CHAPTER XI.

COAST DEFENCES.

132. Object of Coast Defences.—The object of the fortifications known as **coast defences**, is to defend the harbors and coasts of a country against attacks by sea.

When the attack is by forces landed from ships, the arrangement of the defences to resist such attacks follows the general rules of fortification.

When the attack is made by naval forces in war vessels, the defences are somewhat differently arranged, and are made stronger.

On the land fronts the attack will be either an assault or a siege.

On the water fronts the attack will be by war vessels, usually in motion, protected by iron armor, and armed with the heaviest guns of the time. The batteries built to repel such attacks will very likely have to sustain an artillery fire of a greater number of guns than can be brought to bear upon the ships in return. This superiority in number of guns on the part of the vessels must be counterbalanced by greater effectiveness upon the part of the batteries. The batteries should be armed with guns as heavy as those on the vessels, should be well placed, and should be supplied with good bomb-proof covers for the troops serving the guns.

133. Positions of Batteries.—**Roadsteads** in which vessels may anchor and remain for an indefinite time, and **channels**

which vessels have to use to reach definite points, are the principal parts to be defended in a system of coast defence.

A roadstead, or harbor, may be occupied by an enemy simply to make repairs, to recruit, or to await re-enforcements; to make preparations for landing forces that are to operate on shore; or to bombard a city or a place in its vicinity.

The position to be given batteries intended for the defence of a roadstead will be such that the fire of the batteries will reach all the points that an enemy's fleet can occupy. Some of the batteries may be placed on land, and some on water, and in some favorable cases the batteries may all be on land. The batteries on the water may all be fixed, or some movable and some fixed. Shoal places in the water are utilized for the position of fixed batteries, the foundations of which are prepared by using piles, rip-rap of stone, etc. Fixed batteries are to be preferred to movable batteries, although in some cases the great cost of the foundations of the former may make it desirable to use the latter. A roadstead commanded in all its parts by the fire of heavily armed batteries, cannot be occupied by an enemy's fleet until the batteries are silenced. The batteries should be placed and protected so as to make this operation of silencing them a very difficult, if not an impossible one.

A ship channel is a line of communication that an enemy may want to use but not to occupy it. To reach the object of his attack, he may attempt to run by the batteries without trying to silence them, and by doing so save his ammunition and gain time. The channel should therefore be so defended and obstructed that it could not be used by an enemy's fleet until its batteries are silenced.

Batteries, defending either roadsteads or channels, should be placed so that their fires could be concentrated upon the

most important points, and when possible so as to support each other. Whether they are to be closed works is a question of situation and exposure to land attacks.

A plunging fire from a considerable elevation is considered to be the most effective fire against armored ships. In former times, a ricochet fire from batteries situated near the water level was considered to be the most effective. This latter fire has lost its efficiency against the sides of the iron-clads, but is still useful to defend the banks of a river or shores of a harbor against attempts to land troops from a fleet to operate on land.

Batteries placed at an elevation of 100 feet above the water and not less than 1,000 yards from the nearest positions that a ship can take, armed with powerful guns, become formidable defences against naval attack. Their elevation gives them a strong plunging fire and also allows the use of barbette fire. Batteries near the level of and close to deep water are commanded by the ships, and are compelled to use covered defences. Whilst the advantage in the former case was on the side of the battery, it is in the latter on the side of the ships of war.

The positions of the batteries having been selected, the questions of the trace for each battery, the selection of those batteries that can use barbette fire, and those that must use casemated fire, are to be next considered. It is particularly in coast defences that the use of iron for protective purposes becomes so important a matter.

The general rules of fortification apply to coast defences as well as to fortifications liable only to attack by land.

134. Construction of Coast Batteries.—Previous to the introduction of rifled cannon, barbette batteries of earth and casemated batteries of masonry formed the types of coast defences. Masonry forts were built on shoal places in harbors, and castellated masonry structures on projecting points,

which with the batteries along the shores formed the usual coast defences of that period.

The batteries near deep water were sometimes constructed of brick masonry, but more generally of stone. The arch, the piers, and front wall of the casemates were constructed of large blocks of granite. The arched roof was made bomb-proof by earth placed on it, and this roof supported another casemate, or a barbette battery. In this way two and more tiers of fire were obtained to bear upon the channel near the battery. Particular attention was given to ricochet fire, this fire being obtained by the lowest tier of casemates, or by batteries constructed near the level of the water. The latter were called **water** batteries, and sometimes **low** batteries.

These casemated masonry structures are now considered as unfit for the service intended, and when attempts are being made to fortify a coast, they are either torn down or ameliorated. The amelioration consists in diminishing the exterior opening of the gun-port, and protecting it and the face of the wall by iron plates. The new constructions are usually after the manner of Haxo casemates with Gruson's shields, or are iron turrets, etc.

The parapets of the barbette batteries are now made thicker than formerly. In England, the parapet is made 27 feet thick, being composed of sand or sandy material, backed by concrete—17 feet of sand and 10 feet of concrete. If the range is limited to a small field of fire, and the barbette battery is much exposed, embrasures are constructed and the throats protected by iron shields. The low batteries are armed with guns mounted on disappearing carriages (Moncrieff's) that sink into pits or depressions as soon as fired, offering no mark to an enemy's guns. When disappearing carriages are not used, the casemate is employed.

It is well to say, that the casemate of the past was principally useful in reducing the superiority of the enemy's guns

in number, as by its use of two, three, and more tiers of fire, a greater number of guns could be placed on a limited area — a very important object to be attained.

While the masonry coast defences are condemned, distinguished engineers have claimed for them an existing value not to be despised even now. These engineers claim that,

1. The attack by a fleet against a battery is generally of short duration.

2. The accuracy of the naval fire does not particularly endanger the embrasures.

3. The inaccuracy of naval fire is increased by the motion of the ships and by the smoke of their guns.

4. The granite front of the casemate is not pierced at once by a single projectile.

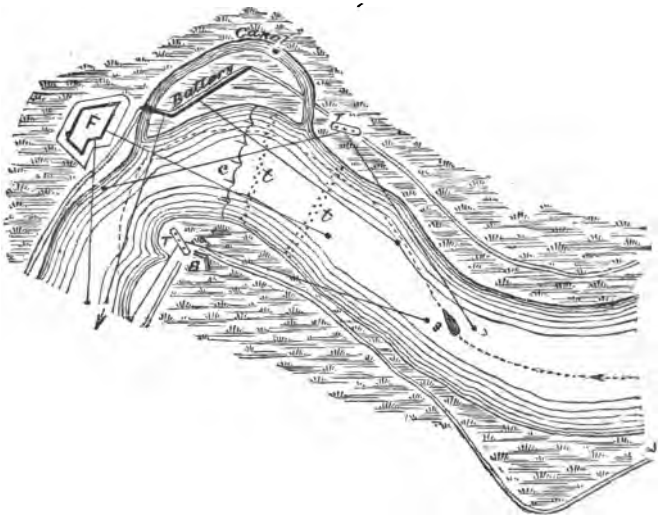
For these reasons, the casemate in actual operation is not destroyed so quickly but that it will be able to do considerable execution among the enemy's ships before it becomes untenable. The fixed position of the battery and the knowledge of the exact distance from the vessel fired at, give the casemate, even though made of granite, considerable powers of resistance still. The iron border, like that used by General Totten around the exterior opening in the face wall of the casemate, has in some cases been added to, until the face of the casemate may be said to be of iron plate backed by masonry. This forms one of the methods used to strengthen it.

135. Example of Defence Proposed for a Channel.— The fire of artillery alone cannot be depended upon to prevent armored ships of war from using a navigable channel. There must be, in addition, obstacles to their progress, which will cause the vessels to be stopped, for a time, under a fire of the batteries at close range. If there be no obstruction to stop the vessels, the batteries will be at the disadvantage of firing at objects in motion, and of being able to fire but few rounds before the objects are out of range. Under these cir-

cumstances, the chances of missing are increased, and the chances of making effective shots are decreased. Placing obstructions to their progress, so that the ships must remain stationary for a time, decreases the chances of missing, and increases those of making effective shots.

An example of the method recommended to defend a navigable ship channel, like that of a river, is given in Figure 56. It is taken from General Brialmont's Treatise on Polygonal Fortification.

Fig. 56.



It is seen that three batteries are placed to command the elbow or turn of the channel and bring a fire upon the reach approaching the bend. General Brialmont recommends the protection of the bend for the reasons, that,

1. A vessel changing its direction, as it will have to do at a turn in the channel, must necessarily slacken its speed.

2. The reduction of speed affords more time to the batteries to fire and reduces the momentum of the vessel at the

time of striking an obstruction placed in the bend to bar her progress.

3. The bend allows a selection of position for the batteries, in which position a better concentration of their fire can be obtained.

It is proposed in the example (Fig. 56) to place a strong fort, F, upon the left bank of the river opposite the bend, and give it such a trace as will allow a strong direct fire on the reach approaching the bend. This fort is to be a strong one, enclosed, and thoroughly flanked.

Upon the opposite point, on the right bank, it is proposed to build a casemated tower, T, and on top of this tower to place three iron turrets. The casemates are to be protected by a glacis; the turrets are to be in a right line, the axis of the three, upon being produced, should intersect the fort, F.

A similar tower with turrets is to be placed on the same side of the river with the fort, and in advance of the bend.

An obstruction, as *c*, is to be stretched across the river at the beginning of the turn in the channel. From the position of the fort and the two towers, it is seen that a vessel kept stationary by this obstruction would be exposed to the concentrated fire of all three of them, and there would be no danger of the works firing into each other.

Low batteries are to be built to increase the volume of fire upon the channel. A strong one is recommended on the left bank in advance of the fort, and one, B, near the tower on the right bank (Fig. 56).

A floating obstruction, *c*, is to be placed across the river at the beginning of the turn in the channel, to act as a barrier to vessels using the channel. In front of this barrier, a line of torpedoes, *t*, or submarine mines, is planted, and across the river in front of the tower on the left bank, and under its guns, another line, *t*, of submarine mines is to be employed.

The canal near the bend is to be employed as a line of

communication around the barrier, if needed, and as a station for monitors and floating batteries.

General Brialmont places great confidence in the use of the casemated towers and iron turrets, preferring them to forts because they require fewer men to man them, are less exposed to capture by assault, and have as effective fire with a less number of guns. The banks of the river being low and level, the necessary command is obtained by high ramparts.

136. Obstructions.—Whether the work is a temporary or a permanent one, great stress is laid by engineers on the value of **obstacles** that will hold an enemy under fire of the work at close range, even for a short time. Valuable as these obstacles are in a work when the approaches are made on land, far more so are they when the approach is by water. Obstructions to an approach by water may be **floating** or they may be **sunken**, that is, hidden under the surface of the water.

Floating obstructions, as a rule, are more easily made, and are more easily removed from a channel than sunken ones. They are the kind usually employed in deep water.

Sunken obstructions ordinarily rest upon the bottom of the channel, and when placed in position are frequently quite difficult to remove.

The common forms of floating obstructions are made of timber booms, rafts, or of ropes. The booms are fastened end to end by strong chains and extend across the channel. In the raft obstruction, the rafts are moored at intervals apart, and the intervals barred by chains. Strong chains, buoyed at intervals, have also been used for the purpose. Obstructions of these kinds should be made strong enough to stop a vessel's headway, by giving way slightly as the vessel strikes them, converting the blow into a push. The rope obstructions are made of strong hawsers held up by small buoys, with smaller ropes hung from the hawsers. Obstructions of this kind are

intended to entangle the vessel's propeller, and by its stoppage deprive the vessel of her motion.

The common form of sunken obstructions are piles, loaded crib-work, sunken vessels, etc. In moderate depths, piles may be driven, either singly or in groups. In crib-work the crib is floated to its place and sunk by filling it with heavy material, as stone, iron, etc. Old hulks towed into place and sunk have been employed. Logs, with one end weighted and the other buoyed, have been used in streams where there is a strong current. They take an inclined position, and present their upper ends toward a vessel coming up the stream, acting similarly to the well-known obstructions, known as "**sawyers**," of our Western rivers.

137. Submarine Mines.—Military engineers consider mines to form a class of obstacles to the approach of an enemy, either on land or water, that gives greater effective resistance with smaller expenditure of ammunition and blood than that of any other kind. A system of harbor or channel defence is now not considered to be complete unless provision be made for a free and liberal use of this class of obstacles.

A military **mine** is an arrangement containing an explosive compound, fixed in a position either under the surface of the land or of water, that can be fired at a particular time.

When this arrangement is placed under the surface of the water it is called a **submarine** mine, or **torpedo**.

A submarine mine is a torpedo, but all torpedoes are not submarine mines. The term, **torpedo**, includes more than mines; it includes those explosive machines which may reach the place where they are to be employed by a motion of their own, or a motion given to them by some extraneous means.

Torpedoes may be divided into two general classes, viz.: **Offensive** and **Defensive**. Offensive torpedoes are those

which reach the place of explosion by some motion imparted to the torpedo. Defensive torpedoes are those which explode at the places where they are fixed in position. This latter class is known as that of submarine mines.

When speaking of the torpedo in coast defences, it is the stationary one that is meant, although it is probable that the movable torpedo will also be employed when an occasion for its use arises.

138. Component Parts of a System of Submarine Mines.—The various parts composing a system of submarine mines are as follows, viz.:

1. The case to contain the explosive compound.
2. The explosive compound.
3. The fuse used to fire the explosive.
4. The means of keeping the mine stationary.
5. The connections of the mine with the shore.
6. The land apparatus necessary to make the system efficient and to control it.

1. The Case.—The case for the explosive may be made of wood, iron, or steel. It must be water-tight, and may be of any convenient form. In strong tidal currents and deep water, where the case is not placed on the bottom, but is held at some distance above it, the spherical form is considered to be the best one. The size of the case should be sufficient to contain the charge, and leave room for air space enough to give it buoyancy.

2. The Explosive.—Gunpowder, gun-cotton, and nitro-glycerine, and the compounds of the latter two, are the explosives ordinarily used. The greatest destructive effect is obtained when the largest amount possible of the given charge is ignited before the case is ruptured. The thickness of the case should therefore be greater for charges that are slow in their action than for those that are quick.

3. The Fuse.—The principal varieties of fuses used to

fire the charge may be classed under the heads of **friction, percussion, chemical,** and **electric** fuses.

The friction and percussion fuses are the familiar ones used to fire cannon and small-arms.

There are many varieties of the chemical fuse. A simple form is that of a thin tube containing sulphuric acid, placed in a mixture of loaf sugar and potassium chlorate. The tube is arranged so as to be broken, or overturned, at the proper time, and to spill the acid in the mixture of sugar and chlorate. Chemical action ensues, producing a flame that ignites the charge and explodes the mine.

The electric fuse consists of a small plug of wood that holds the ends of two insulated wires in place. The ends of the wires are bare, and are connected by a platinum wire of much smaller size, or separated by a small interval of about one-twentieth of an inch. The bare ends of the insulated wires and the platinum wire are surrounded with a very sensitive compound called the *priming*, and over this is placed a small metallic case containing a detonating charge.

The fuse is placed in the charge, and its action is as follows, viz.: The electric current passing through the insulated wires heats the platinum wire *red hot;* this red-hot wire ignites the priming; this detonates the charge in the cap; this latter fires the charge of the mine. The heating of the platinum wire is due to the resistance it opposes to the passage of the electric current; hence the name, "**resistance fuse,**" to designate this kind.

When, instead of the platinum wire, the ends of the wires are separated by a slight interval, the electric current passes from one wire to the other by sparks; the sparks ignite the priming; the detonation of the fuse is followed by the explosion of the mine. The electric current in this fuse is one of "**high tension,**" as it has been called, and the fuse is known as the "**tension fuse.**"

Electricity developed by frictional machines is the kind required for fuses of the latter class, and that of the voltaic battery for the former. Both kinds can be fired by the magneto-electric machine.

Some authors divide the electric fuses into two classes, "**high tension**" and "**low tension.**"

Fuses are sometimes made to combine both methods of firing, so that either kind of electricity may be used.

Experiments prove that a greater explosive effect is produced when a charge is fired by **detonation,** than when it is fired by **deflagration.**

These experiments show, that considering the explosive energy of gunpowder as 1 when fired by deflagration, that the corresponding energy of gun-cotton was 3, and nitro-glycerine, 5. Keeping the same unit and firing the charges by detonation, the energy of the gunpowder rose to 3, that of gun-cotton to 6.5, and of nitro-glycerine to 10.

These experiments show that the charge in a mine should be exploded by detonation whenever the greatest explosive effect is desired.

4. Means Used to Keep the Mine Stationary.—When the mine is to rest upon the bottom of the harbor or channel, there is little difficulty in keeping the case in its place.

In deep tidal waters this is not so easy to do. The destructive effect of an explosion of a mine varies, very nearly, as the cube of the distance of the mine from the object affected, and is greater when directly under the object than when at the same distance on one side of it. It is therefore desirable to have the mine in contact with the vessel, and under its bottom, when it is exploded.

Mines should therefore be moored so as to be safe from contact with light floating objects, but near enough to the surface to be struck by the bottom of a ship as she sails over them.

A common anchor and chain or wire rope are the means usually employed to fix a submarine mine in its place, though any heavy mass and a common rope may, on an emergency, be employed. In very deep water it may be necessary to use guys to keep the case from swinging too much. A mine moored by a single chain in water 50 feet deep, has been known to swing with a radius of 20 feet from the vertical. Hempen ropes and chains are apt to twist, and pull the case from its place, which the wire rope does not do, making its use preferable. The larger the case, the greater is the displacement produced by the action of a strong current.

5. **Connections with the Shore.**—Connections with the shore are not necessary, excepting for those mines that are to be fired by electricity. In the latter case, the connections are made by means of insulated wires. These wires must be kept in a good state of insulation and safe from injury. The ordinary rules for laying and preserving intact cables used for telegraphic purposes must be observed.

6. **Land Apparatus.**—Submarine mines fired by electricity from the shore require **electrical machines** to generate electricity, and an **electrical apparatus** to fire the charge. In conjunction with these, there should be a system of **ranges** to determine the position of each mine, a **telegraphic communication** between the different stations on shore connected with the system of mines, and **telescopes** for observers to watch the approaches leading to the mines.

The electrical apparatus should be arranged to **test** the insulation and perfect working of the system, to **announce** the fact when a mine is struck, to **record** the number and position of the submarine mine struck, and to **fire** the charge of a particular mine or group, when it may be desired.

The announcing and recording the particular mine struck by a ship is based upon the same principle as that employed

in the common hotel annunciator. A pressure upon a knob or button in a room of the hotel closes or breaks an electric current; this causes a bell to ring in the office, and also discloses a number upon the annunciator; the bell by its ringing attracts attention, and the number corresponds to that of the room in which the knob or button was pressed.

The test for insulation and for good working of the parts is obtained by **testing batteries**; the firing of the charge, by **firing batteries.** The difference between these two batteries is in the respective powers of the batteries to produce currents of electricity.

The testing battery furnishes a current too weak to fire the fuses, but strong enough to announce the striking of one of the mines, or an interruption of the working of the system. The firing battery furnishes a current powerful enough to ignite the fuse and to fire the charge of the mine.

A **switch** is arranged so that the currents of both batteries, or that of either one, may be broken at will. The current of the weak battery being closed, a change in the switch may be made to break this current, and transfer the current of the firing battery to the same circuit.

By means of such a system, a vessel striking a mine can be made to notify the parties on shore the number of the particular mine struck; and a simple change of a switch can convert the current of electricity into one sufficient to explode the mine before the ship can move but a short distance.

In such a system, the mine may be made automatic by arranging the circuit so that when the mine is struck, the circuit of the firing battery passing through it shall be closed at that moment. The closing of the circuit causes instantaneous ignition of the fuse and explosion of the mine.

In a system of this kind, the mines are not made automatic until the immediate necessity of their use should require it. Otherwise, the enemy, by grappling for them or by using

devices to shock the mines, might explode them prematurely.

If left unprotected, and not automatic, they might be removed during the night by similar methods. To guard against this latter, observers keep constant watch upon the system, and note all suspicious circumstances. Loaded cannon trained upon the approaches to the mines, and upon the spots occupied by them, can be connected with the electric currents so that upon the disturbance of a mine at any locality, the cannon trained upon that spot can be at once fired either at will or automatically. The strictest secrecy as to the true positions of the mines should be observed.

139. Requisites of a Good System of Submarine Mines.—Assuming the system to be an electric one, which will be the case when employed for the defence of important points, there are certain requisites which seem necessary that such a system should possess.

These requisites are as follows, viz.:

1. The system of submarine mines intended for defence of a particular point, after it has been prepared, should at all times be certain in its action.

2. It should be provided with electrical machines and apparatus easily understood and manipulated by persons of ordinary intelligence, and not requiring electrical experts.

3. It should have the mines prepared so that they may be fired either by contact, or "at will."

4. It should give notice at once of the breaking of, or any damage to the wires or cables connecting the mines with each other, and with the shore.

5. It should give notice of the displacement of any mine, like that caused by sinking.

6. It should denote the particular mine struck, or displaced.

7. It should be so arranged that under no circumstances

will it be possible for a key or switch to be left in its wrong position.

8. It should indicate its working condition and perfect insulations by tests of a simple and easy kind.

140. Location of Submarine Mines.—The general rules given for obstacles should, when applicable, be used for submarine mines. An obstacle is considered most effective when it stops an enemy under the fire of a work at close range. Submarine mines should therefore, as far as possible, be located at points obstructing a channel that is commanded by heavily armed batteries, and they should be arranged in lines that can be enfiladed by these batteries.

The method employed to lay these mines is to prepare first a map, upon a large scale, of the harbor and channels to be defended. Upon this map the positions of the batteries are located, and the points to be occupied by the mines are marked. This having been done, the corresponding points in the water are determined by means of shore **ranges** with the proper instruments.

The case is charged on shore, loaded upon a row-boat or steam launch, and carried to the point it is to occupy. Connections are then made between it and the insulated wires and cables leading to the shore apparatus. The mine is then anchored in position, and is ready for action.

To deceive the enemy as to the real positions of the mines, dummies are frequently employed in connection with false ranges. These dummies may be connected with a telegraphic system by means of which the position of the enemy's parties would be made known when attempting to find and remove the mines of the system.

141. Automatic Mines.—It has been seen how a mine of the electric system can be made to fire by contact, or by will. The mines just described require electric communications with the shore.

There are other kinds of **automatic** mines besides these that are fired by the touch of a passing vessel. They are fired, either by a **detonating** or a **chemical** fuse.

A simple form of the detonating arrangement that has been used is as follows:

A solid shank is made to project from the bottom of the mine case, and is terminated with an eye, into which the chain, or wire rope, attached to the anchor is fastened. To the neck of this shank, by means of small projections, a firing pin, a strong spring, and a trigger are connected. The pin, upon being pushed upward by the spring, penetrates the bottom of the case through an aperture made water-tight by a water-proof cover.

A fulminate is placed over this aperture, in contact with the water-tight cover of the vent, and in contact with the charge of the mine. A small cord is attached to the end of the trigger, carried up, and fastened to a projection upon the top cover of the case. This top is a false cover, with the projections rising from its surface.

The action of the apparatus is as follows:

The mine having been charged, and anchored in place, the trigger is set. Any floating or moving object striking the projections of the top cover, or the case itself, knocks the false cover off. As this cover falls off, it pulls the trigger; the firing pin, driven by the spring, pierces the water-proof covering placed over the vent, and fires the fulminate; the detonation of the fulminate explodes the mine.

Mines of this kind are frequently called "**mechanical**," from the mechanical contrivances employed to fire them.

Automatic mines when fired by chemical fuses are made upon a similar principle. Leaden tubes are fixed in the top and sides of the mine case, and are connected with the charge in the case. In these leaden tubes chemical fuses are placed. A vessel striking against the case, or the projecting

tubes, bends one or more of the leaden tubes. The bending of the tube breaks the glass holding the acid, and spills it upon the mixture of the fuse. Ignition of the priming ensues, and an explosion of the mine follows.

Automatic mines, having no connection with the shore, are also made, to be fired by the electric fuse. The arrangement of a mine of this kind is such that the materials are all ready to generate the electric current, but not to generate it until the case is struck by a vessel. Mines of this class are made to explode, when they are removed from the positions in which they are anchored, by persons or causes other than those employed to place them.

142. Advantages of Automatic Mines. — Automatic mines possess the advantages of being quickly and easily prepared; of needing no electric connections with the shore; and of exploding when the vessel is in immediate contact with them.

143. Disadvantages of Automatic Mines.—Automatic mines after they have been anchored in position, have the disadvantages of being dangerous to friend as well as to foe; of giving no indications as to their conditions of efficiency; of giving no indications as to whether they are in their proper places; and if accidentally removed, of being worthless, and possibly dangerous to the defence.

144. Component Parts of a Good System of Coast Defence.—A system of coast defence, therefore, consists of—

1. Strong and heavily armed batteries.
2. A system of floating and stationary obstructions.
3. An efficient system of submarine mines.

There should be, in addition to these, for an important harbor:

4. Vessels of war.
5. Torpedo boats and movable torpedoes.

Under the head of vessels of war are to be included moni-

tors, floating batteries, and the offensive and defensive appliances of naval warfare.

Under the head of movable torpedoes are to be included all torpedoes that have motion imparted to them, as well as these that move by a force generated in the torpedo.

A practical and efficient defence of a harbor like that of New York City, in time of war with one of the great powers of Europe, would require a combination of all these five parts, just enumerated.

CHAPTER XII.

INFLUENCE OF IRREGULARITIES OF SITE.

145. General Principles Common to all Systems of Fortifications.—Whatever may be the system of fortification that an engineer employs to defend a site, there are certain general principles common to all systems which he should observe. These principles may be briefly stated, as follows:

1. A fortification of the permanent class should be made strong enough to make it secure against assault.

2. It should be so arranged that all ground exterior to the work within cannon range, liable to be occupied by an enemy, can be swept by strong and direct fire of the defences.

3. It should have the ditches thoroughly flanked.

4. It should have all masonry protected from both indirect and direct fires of an enemy.

5. It should have the principal lines of the defences so directed that they will not be exposed to enfilade and reverse fires of an enemy. If this be impracticable, the lines must be **defiladed.**

6. It should be provided with ample and commodious bomb-proof shelters.

7. It should be provided with easy and well-protected communications that can be used by the garrison at all times to have free access to all parts of the work, and to the exterior.

8. The fortification should be proportioned to the garrison that can be spared to occupy it.

9. It should have all the advantages that the natural features of the site may afford, in arranging accessory defences by which the work may be strengthened.

The **first** of these principles is observed by using steep scarps on dry sites, and wet ditches where there is water.

The **second**, by giving proper positions to the lines of the work, and adapting the trace to the features of the ground.

The **third**, by throwing forward some and by retiring other lines of the work, making re-enterings in the trace, as in the bastion and tenaille traces; or by using auxiliary works, as caponiers in the polygonal system.

The **fourth**, by lowering the top of the masonry sufficiently far below the level of the work in front of it, or by using masses of earth to shelter it.

The **fifth**, by giving the principal lines such directions that their prolongations will fall on ground that an enemy cannot occupy. This ground may be unfit for occupation in consequence of its natural features, as in case of marshy spots, water, etc., or it may be very close to a heavy direct fire of other parts of the fortification, as in the case of fronts where the salient angles are very obtuse.

The **sixth**, by building vaulted rooms in the ramparts, within traverses, and at suitable places where the roofs and sides of the rooms can be covered with a sufficient thickness of earth to make them bomb-proof.

The **seventh**, by building roads, ramps, posterns, stairs, and sally-ports, such as are described in the details of the bastion and polygonal traces of fortification. The communications should be made as direct and commodious as the circumstance of each case will allow, and arranged so as to be safe from an enemy's fire. When possible they should be swept by the fire of the works in their rear. The communi-

cations of one work should not be dependent upon those leading to another.

The **eighth**, by estimating the kind and number of troops that can be spared to defend a position in time of war, and arranging the fortifications of the position so that there will be space for the accommodation of the troops, and no greater length of interior crest than the garrison can competently defend.

The **ninth**, by the employment of accessory defences, as abatis, mines, torpedoes, inundations, etc.

146. Irregular Sites.—The command of a work over a level site or one that is practically so, is obtained by throwing up ramparts of sufficient height for the purpose.

The position and the direction given to a line of a work are in the discretion of the engineer, so far as the natural features of the ground on level sites are concerned.

When the site is upon irregular ground, the engineer can no longer lay out the lines of a work at will, but must place them in such positions, and give them such directions, that the lines may satisfy the conditions common to all permanent fortifications.

The requisite command of a line over the exterior ground is more easily and more economically obtained by placing the line upon the highest portions of the site.

The highest portions of the site having been selected, the engineer endeavors to give such directions to the line as will enable it to sweep with direct fire the ground in its front, as will avoid making dead spaces, and will prevent its exposure to enfilade and reverse fires. A careful study of the natural features of the ground and a thorough acquaintance with the principles of defence of a position are necessary to the engineer for this purpose.

It nevertheless happens frequently that these three conditions cannot all be satisfied at the same time, and some one

of them has to be sacrificed to the needs of the others. This is the case frequently when there is high ground within cannon range of a work that cannot be included within the lines of that work. The best direction for the lines of the work, so far as the high ground is concerned, is to have them parallel to the crests of the high ground. Placing the lines in this way may prevent a thorough sweeping of the ground in front of one or more of the lines by strong direct fire, and to obtain this latter fire the engineer may be obliged to give the lines such directions that they will be exposed to enfilade. The last condition is therefore sacrificed to fulfil the one of direct fire. When this is the case, the engineer must use some method to palliate the evil arising from the direction given to the line.

147. Defilade.—An enemy that occupies ground commanding a work within cannon range, can bring a plunging fire from it upon the work. If the work has any of its lines so placed that their prolongations would intersect the high ground occupied by an enemy within cannon range, those lines would be exposed to enfilade, and possibly to reverse fire.

Security of the defence requires that the terre-plein of a work thus exposed should be screened from these fires. The method used to effect this purpose is known as that of **defilade.**

There are three ways in which the defilade of a work is effected, viz.:

1. When the terre-plein is fixed it may be defiladed from a direct plunging fire by making the parapet higher.

2. When the interior crest is fixed, the terre-plein may be defiladed from this fire by increasing its distance below the interior crest.

3. When the terre-plein is exposed to a plunging fire quite oblique to the line of interior crest, or on a prolonga-

tion of it, the terre-plein may be defiladed by means of traverses.

The **first** of these methods is the usual one employed in temporary works, as the terre-plein and surface of the ground are usually one and the same.

The **second** is the method usually employed in permanent works, as the interior crest of this class is usually fixed in position before the terre-plein.

The **third** method is employed in both temporary and permanent works.

Assuming a parapet of **eight** feet to be sufficiently high to shelter the troops upon its terre-plein from a direct fire of an enemy, the method of defilading this terre-plein of a permanent work from a direct plunging fire, is as follows:

A plane is passed through the interior crest of the parapet and **six** feet above the ground from which the plunging fire comes; the terre-plein is then made parallel to this plane and not less than **eight** feet below it; the terre-plein thus arranged is defiladed from the direct plunging fire and is safe to be used by the troops.

A plane passing through a line of interior crest and six feet above the ground from which a plunging fire comes, is called a **plane of direct defilade.**

148. Example.—Suppose two of the faces of a given work to be exposed to a plunging fire from ground lying between the interior crests of the faces when prolonged, let it be required **to defilade the terre-pleins of these faces from this plunging fire** (Fig. 57).

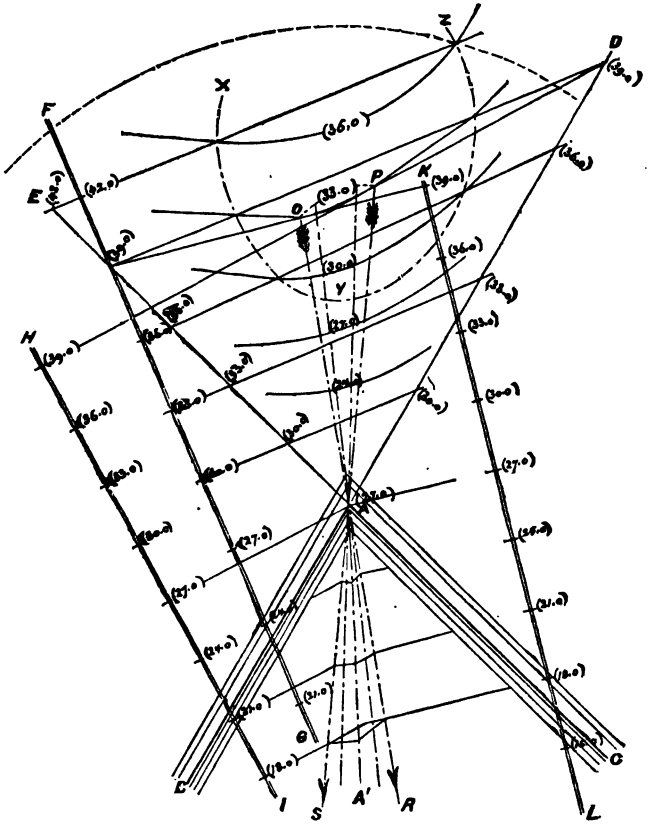
Let **A B** and **A C** (Fig. 57) be the interior crests of two faces of a work exposed to a plunging fire as described, and the contours (24.0) (27.0), etc., represent the features of the ground included between these faces prolonged.

With **A** as a centre, describe an arc with a radius **A F**, equal in length to the range of the cannon in the possession of the

enemy. The ground included within this arc and between the faces prolonged contains, by hypothesis, that part from which a plunging fire can be had upon the work.

Construct the scale of slope, **F G**, of the plane of the two crests, **A B** and **A C**, and find the intersection of this plane with a surface parallel to that of the ground, but **six** feet higher. The dotted line, **X Y Z** (Fig. 57), represents this line

Fig. 57.



of intersection. Assuming that the line of fire of the enemy will not be more than five feet above the ground on which they stand, it is evident that this work is exposed to no

plunging fire, excepting from that portion which lies above this curve, **X Y Z.** This portion above this line of intersection is called the **dangerous** ground.

To defilade the terre-plein from the fire of this dangerous ground, pass a plane through the interior crest **A B** and tangent to this imaginary surface that is six feet above the natural ground. Construct its scale of slope, **I H.** This tangent plane will be a plane of direct defilade for that face, **A B.** The terre-plein held parallel to this plane and eight feet below it, will be defiladed from the direct plunging fire of the dangerous ground.

Through the face **A C** pass a similar plane and construct its scale of slope, **K L.** This plane will be a plane of direct defilade for that face, and if its terre-plein is made parallel and eight feet below it, the terre-plein of the face, **A C,** will also be defiladed from the plunging fire.

It is usual to make the terre-plein parallel to the plane of direct defilade, but this need not be so. It is only required that no part of the terre-plein, and especially its rear, shall be less than eight feet below the plane of defilade.

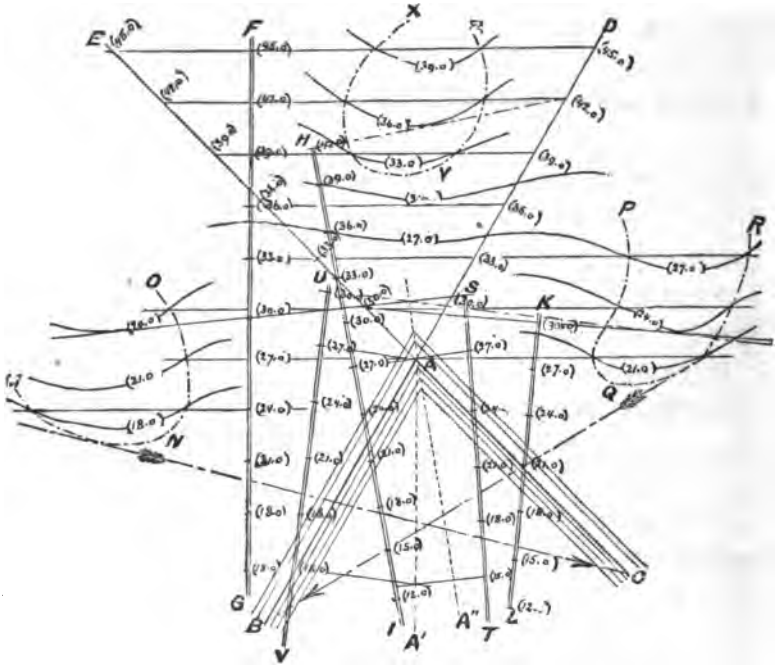
If the terre-pleins of the two faces have considerable inclinations, they would form, by their intersection, a rut or gutter if they were kept as plane surfaces. This gutter is modified by making it a conical surface, as follows:

In examining the dangerous ground (Fig. 57), it will be seen that the points **O** and **P** are the only ones from which the enemy's fire grazing **A** passes eight feet above the terre-pleins; every line of fire through **A** between the lines of fire, **O A R** and **P A S,** will pass more than eight feet above the terre-pleins in this angle, **S A R.** Hence, let **A** be taken as the vertex of a cone whose elements prolonged are tangent to the raised ground within the angle **P A O**; these elements will all pass eight feet above the terre-plein; the two terre-pleins are then joined in this angle **S A R** by a conical surface

parallel to the cone whose vertex is at **A**, and eight feet below it; this conical surface modifies the gutter that would otherwise exist as an obstruction.

149. Problem.—Suppose two of the faces of a work to be

Fig. 58.



exposed not only to a direct plunging fire, but also to reverse fire, let it be required **to show how the terre-pleins of these faces may be defiladed** (Fig. 58).

Let **A B** and **A C** (Fig. 58) be the faces of the work, and the contours (21.0), (24.0), (27.0), etc., represent the irregular features of the ground. Construct the scale of slope, **F G**, of the interior crests, and find its intersections with an imaginary surface parallel to the natural surface and six feet above it. Let **X Y Z**, **M N O**, and **P Q R** be the curves of intersection

cut out of this imaginary surface, within the limits of cannon range of the work.

The face **A B** is exposed to a direct plunging fire from the ground lying above the curves **M N O** and **X Y Z**. It is also exposed to an oblique reverse fire from the ground above the curve, **P Q R**.

The face, **A C**, is exposed in like manner to a direct fire from the ground above the curves, **P Q R** and **X Y Z**, and to a reverse fire from the ground above the curve, **M N O**.

The terre-pleins of the faces are defiladed from the direct plunging fires in the way shown in the last problem. Since there are two distinct portions from which the direct plunging fire can come, it is necessary to defilade from each. If the terre-plein is defiladed from the ground that gives the greatest plunging fire, it will also be defiladed from the other portion. The scales **H I** and **K L** are the scales of slope of the two planes of direct defilade for the faces of the work.

To defilade these terre-pleins from the reverse plunging fires, it is necessary to use a screen that will intercept the fires from the ground higher than the curves **M N O** and **P Q R**. The screen ordinarily used is a **traverse**. Let a plane be passed through the crest **A B** and tangent to the imaginary surface above the curve, **P Q R**; there will be no direct fire above this plane, since it is six feet above the natural ground enclosed by the curve, **P Q R**; a traverse in rear of the terre-plein of **A B**, the top of which is in or above this plane, will screen the terre-plein from reverse view of the ground above **P Q R**.

In a similar manner, a traverse in rear of the terre-plein of the face, **A C**, the top of which is in or above the plane passed through **A C** and tangent to the imaginary surface above **M N O**, would screen the terre-plein from reverse view of that ground.

The planes passed through the interior crests and tan-

gent to the imaginary surfaces in rear of them are termed **planes of reverse defilade.** The scale U V is the scale of slope of the plane of reverse defilade for the crest A B, and S T for the crest of A C. These planes intersect in the line A A′.

If a single traverse is used to defilade both terre-pleins from reverse fire, its position may be along the line of intersection of these two planes of reverse defilade.

A traverse placed along this line of intersection to defilade the terre-pleins, is required to be of less height than in any other position.

If it is inconvenient to place it in this position, and it is desirous to defilade both terre-pleins by it, the top of the traverse must be raised until it is, at least, *two* feet above the higher of the two planes of defilade.

The traverse is made long enough to defilade both terre-pleins throughout their entire lengths. Its length for this purpose is determined by drawing through the extremities of the faces, B and C, two lines tangent to the curves, M N O and P Q R. The point of intersection of these tangents with the line of intersection A A′, that is farthest from the salient, A, determines the length of the traverse.

It is sometimes inexpedient to use a single continuous traverse to defilade these terre-pleins. Instead of only one, several traverses may be employed, combining them in position by a method similar to that used for placing the traverses on the ravelin covered way in the bastion trace.

150. Traverses.—The term, **traverse,** is applied to a mass of earth placed across a line of fire to intercept the missiles coming along that line. The traverse used when the fire is a direct reverse one, is usually called a **parados.**

An engineer is able, by the use of traverses, to locate his lines so as to obtain the best positions for direct fire, not-

withstanding the lines may be exposed to enfilade and reverse fires. Traverses, however, have the serious defect of using space that might be advantageously employed for guns, and of restricting free communications along the terre-plein upon which they are placed. Their construction in permanent works differs from that employed in temporary fortifications only in the details and not in principle, being made stronger and more durable in permanent than in temporary works.

The thickness and height of a traverse having been determined, its upper surface is arranged with slopes to allow drainage.

The sides of the traverse, from the top and as far down as they are exposed to fire, should have a slope not greater than that of the natural slope of the earth. Below the plane of fire, the sides may be revetted or left at the natural slope of the earth of which they are made.

Traverses placed to defilade the work from very oblique, or enfilade fire, have their upper surfaces higher than the superior slope of the parapet. Traverses of this class have their upper surfaces run out, over the superior slope, until they intersect the exterior slope of the parapet that is produced above the exterior crest to meet them. Care is taken to have sufficient thickness for the traverse to make it effective, and, when there is room, to arrange the traverse for a bomb-proof shelter.

151. Problems of Defilade.—Problems of defilade are easily solved by traverses, if it be expedient to use them. To solve a problem of defilade, it is shown, from what precedes, that an engineer must know, as follows:

1. The positions of the interior crests of the lines to be defiladed.

2. The positions which an enemy can occupy to obtain plunging, enfilading, and reverse fires upon the line.

3. The limits beyond which the effects of these fires may be neglected.

4. The natural features of the ground upon which the lines are to be placed, and of the ground that an enemy can occupy within cannon range.

The latter information is obtained from an accurate map, upon which the features of the ground are represented by topographical signs, and by horizontal contours.

The limits of an enemy's fire are determined by knowing the range of the gun that an enemy will use in an attack on the works, and the positions of covering masses that screen the lines wholly or in part.

The positions from which plunging fires can be had by an enemy, are determined by supposing the natural surface of the ground, as shown on the map, to be raised a distance of six feet, and finding the dangerous ground by the methods already shown. This distance of six feet is taken as the vertical limit, beyond which an enemy's battery will rarely ever fire; since, to place his guns higher than this above the surface of the ground, would hardly repay by its advantages for the extra amount of labor required to do it.

It has been usual in the past to divide the exterior ground into zones, corresponding to the periods of operations into which sieges are divided. This division will hardly be necessary in the future, since the use of modern guns makes the very beginning of a siege the period when defilade is most important.

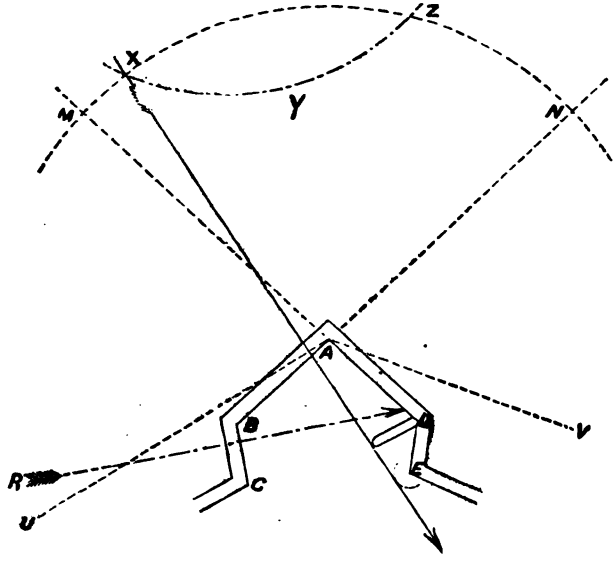
The positions of the magistrals and crests of the lines are marked upon the map. The two most general cases will be those where the plan and command of the lines are definitely fixed, as in the two preceding problems, and when the plan is fixed but the command is only approximately given.

152. Problem.—Suppose the plan of a bastion to be fixed,

but the command only approximately given, let it be required **to defilade the bastion in the most advantageous manner** (Fig. 59).

Let **A B C D E** (Fig. 59) represent a bastion fixed in plan, but the command of which may vary within small limits.

Fig. 59.



Suppose the lines **A U** and **A V** to pass through collateral works that, with the main work, screen the bastion from all fires of an enemy in the angle **U A V**. With **A** as a centre and a radius **A M** equal to the range of the enemy's cannon, describe the arc **M N**. The dangerous ground from which the bastion is to be defiladed is included between the lines **A U**, **A V**, and the arc **M N**.

The most favorable case, when fixing a command for the salient, will be that one where a plane can be passed through **A**, and lie six feet above all the ground within the limits

named, and when it will be practicable to place the interior crests of the bastion in this plane.

The relations existing between the relief and flanking dispositions of the trace may not admit of the flanks being placed in this plane. If this cannot be done, the next most favorable case will be that one in which the faces and flanks can be placed in a plane that passes above all the dangerous ground, except that part in the angle M A N. Suppose such a plane to be passed through A, and the interior crests placed in it. It is evident that the bastion will then be exposed only to the direct plunging fire from the ground above this plane.

Let the curve X Y Z (Fig. 59) represent the dangerous ground when such a plane is used. To defilade the bastion, it will only be necessary to pass planes of direct defilade through the crests of the faces, and place the terre-pleins at the proper distance below them.

It is possible, however, that in placing the crests of the flanks in these planes of direct defilade, that it may lower the parapet of one of them enough to expose the opposite face to a reverse fire. That is, the crest of the parapet B C being in the plane of direct defilade through A B, may from its command expose the face A D to a reverse fire (Fig. 59).

Suppose this to be the case with the flank D E, and that the face A B is exposed to reverse fire, it is evident that the remedy is to raise the crest D E until it is in the plane of the curve X Y Z; this plane being passed six feet above all dangerous ground except that above X Y Z.

The result of this action is to screen the face A B from reverse fire, but it exposes D E to the plunging fire from the ground above X Y Z, since it raises the crest of D E above the plane of direct defilade. To defilade this flank when raised to this position, a traverse must be used. It is placed at the shoulder angle D, and extends far enough back to intercept

all the fire from the high ground above X Y Z upon the terre-plein of the flank and at the curtain angle.

If it is not practicable to hold the interior crests of the faces and flanks in the planes just described, it will be necessary to divide the bastion by a traverse, either placed along the capital or upon some other line, and defilade the exposed portions, as in the previous examples.

153. Necessity of Defilade.—The accuracy of fire attainable by modern fire-arms renders the defilade of a permanent work an imperative necessity. Every means must be employed to screen the guns and gunners from an enemy's view within range of his cannon.

In connection with defilade, protection must be given against curved and vertical fire, since the problems of defilade consider those trajectories only that approach very nearly to straight lines.

154. Accessory Defences.—Accessory defences, classed as **obstacles** in temporary fortifications, are to be freely used in defence of a permanent work. Abatis, wire entanglements, palisades, pickets, military pits, torpedoes, etc., can be improvised and placed in position when the necessity for their use arises. Marshes, water-courses, precipices, and other natural features of the ground that admit of being made into serious obstacles, should be prepared in advance.

Water, especially where the site is level and at a slight elevation above the water-level, may be employed to fill the ditches, and in some cases to inundate the approaches to a work. In some localities the ground is favorable to the construction of dams that may be built to form ponds, and to overflow certain portions of the ground around the work. The dams, when built, should be where they would be secure against an enemy's attack.

Mines are considered important defensive means, and form a part of the permanent preparations to be arranged in ad-

vance of the need for them. All means that would in any way delay the progress of the enemy's trench-works, and add to his labors in building them, should be provided for the defence of a permanent work. Every effort should be made to arrange the defences, so as to make an approach of an enemy to attack them, a difficult and perilous matter for him to undertake.

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